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VOLUME VII.

THE PROBLEMS OF INTERNAL MEDICINE

BY WILLIAM SYDNEY THAYER

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To recognize, to prevent, to protect, to heal—these are, in the broadest sense, the tasks of internal medicine now as ever. But how different are the problems which occupy our attention to-day from those of the period commemorated by this Congress. Let us for a moment glance back at the medicine of the close of the eighteenth and the beginning of the nineteenth centuries. For over two hundred years the blind and binding faith of the Middle Ages, the faith that had so long fettered the human mind, had been slowly giving way before the forces of reason and truth. Now and again with ever increasing frequency, great and courageous minds had risen above the clouds of medical tradition and dogma which had smothered the understanding and reason of mankind, as if, indeed, medicine were a part of the religious doctrine which ruled the world. For truly the medicine of the Middle Ages was largely a matter of faith, and as a matter of faith one in which reason beyond a certain point was heresy and sacrilege. Vesalius with genius and courage had begun to with-

draw the veil from naked and iconoclastic truth. Harvey had made his great discovery. Glisson had demonstrated his theory of irritability. Mayow, with his "Spiritus nitro-aëreus," had anticipated the discovery of oxygen. Leeuwenhoek and Malpighi and Hooke had opened to the human eye the realm of the infinitely small. Bacon and Descartes and Newton and Locke had introduced into the world a rational and natural philosophy. Locke, himself indeed a wise physician, had pointed clearly to the true path of medical progress. "Were it my business," says he, "to understand physick, would not the safer way be to consult nature herself, in the history of diseases and their cures, than espouse the principles of the dogmatists, methodists, or chymists?"

But the clouds of medical tradition were slow to clear away. Gradually, however, the first "lonely mountain peaks of mind" were followed by an ever increasing number of earnest and untrammeled students. In the seventeenth century the opportunity to give one's life freely to the search for truth had become more and more open to all. The mysticism and animism of Stahl, which, in the early part of the eighteenth, hung over the medical world, was already breaking away. The study of the natural sciences was pursued more eagerly and generally than ever before. Réaumur and Black and Haller and Spallanzani and Hunter and Priestley and Lavoisier had lived. Morgagni, sweeping aside the dogmatism of the old schools, had demonstrated the local changes in many diseases and had opened the way for the objective pathological anatomy of Bichat. In the field of practical medicine such men as Sydenham and Morton and Torti and Lancisi practiced and taught much which holds good to-day. Boerhaave had introduced clinical instruction. Cullen and Cheyne and Huxham and Pringle and Heberden and Van Swieten and De Haen were all in

many ways true and faithful students; yet methods and doctrines that were often strangely fantastic still held general sway—such, for instance, as the Brunonian system. A perusal of the writings of Stoll, one of the wisest practitioners of his day, cannot fail to impress one with the meagerness of the basis of anatomy and physiology, normal and pathological, on which medicine rested, the almost entire lack of diagnostic methods, the absence of a rational therapy—how much of the conjectural, how little of the scientifically exact there was in medicine.

Diagnosis, based largely upon gross clinical conceptions, was necessarily vague and uncertain.

Prophylaxis, in the absence of any certain knowledge of the causes and manner of origin of disease, was devoid of any sound basis.

Treatment was almost wholly empirical, and, where it was not empirical, it was frequently based upon some theoretical system so arbitrary and dogmatic that the unfortunate sufferer was too often stimulated or purged, fed or bled, as he fell into the hands of a Brown or a Broussais, rather than according to the nature of his malady.

In the Dictionnaire de l'Académie française for 1789, a year which marks the end of an era in the world at large, one finds the following definition: "Médecine. *s. f.* L'art qui enseigne les moyens de conserver la santé & de guérir les maladies. (La médecine est in Art conjectural. * *)" Medicine a conjectural art! Such was the estimate placed upon our profession by the French Academy a little over one hundred years ago.

But the seeds of a new life had been sown and the germination had already begun. Even as these words were written Lavoisier, too soon to fall a victim to the premature explosion of the forces of pent-up freedom, was in the midst of his great work. In 1796 came the introduction of vac-

cination by Jenner, and but a few years later, Bichat with his wonderful genius, took up the thread dropped in Morgagni and placed anatomy and physiology, normal and pathological, on a basis of accurate observation and experiment. Hand in hand with the introduction of exact methods of anatomical and physiological observation, Auenbrugger, in 1761, had demonstrated in his *Inventum Novum,* a method of physical investigation which, for the first time, enabled the physician to determine changes in size, shape, and consistency of the thoracic organs. At first unnoticed by the world, this important discovery was destined to gain a sudden general recognition in the early days of the nineteenth century. With the spread of knowledge of the gross pathological changes in disease which followed the inspiration of Bichat, the work of Auenbrugger, expounded by Corvisart, became a common possession of the medical world, and, less than ten years later, Laënnec, by the introduction of mediate auscultation, opened possibilities for accurate physical diagnosis such as had not been dreamed of in the ages which had gone before.

With the great school of French observers which followed Laënnec, Andral, Chomel, Louis, Bouillaud, and Trousseau, with Skoda and Schönlein in Germany and Addison and Bright and Stokes in England, the exact association of clinical pictures with local anatomical changes made great advances. Typhus and typhoid fevers were distinguished; the relation between albuminuria and renal disease was demonstrated; the association of endocarditis with acute rheumatism was discovered; the corner-stone of our knowledge of cerebral localization was laid. Clinical diagnosis was becoming more than a conjectural art.

In the meantime physiology was making great strides. Majendie, Bell, Johannes Müller, Beaumont and finally Claude Bernard, and a host of their followers, were shed-

ding light upon many obscure corners of our knowledge of the vital functions. In the hands of Müller the microscope began to open up new fields of study which were destined in a few years through the cultivation of the genius of a Virchow and a Max Schultze to bear a noble harvest. The "great reform in medicine" which followed the introduction of the cellular pathology laid solid foundations for much which is most vital in our anatomical and physiological and pathological knowledge of to-day, and the correlation of these observations with the results of accurately recorded clinical studies, the application of the microscope to the study of the urine, the sputa, the blood, to pathological neoplasms, to exudates and transudates, soon brought new material for the rising edifice of a rational, exact diagnosis. The sphygmograph, the thermometer, the ophthalmoscope, the laryngoscope, the binaural stethoscope, the stomach tube, the various means for studying the blood-pressure, all have brought their aid, while but yesterday the discovery of Röntgen has given us new and unhoped for diagnostic assistance.

At the same time physiological chemistry which, with the work of Berzelius on the urine, had taken its place by the side of the more purely physical methods of investigation, has year by year given us greater diagnostic assistance in the analysis of the different secretions and excretions of the body and in the explanation of the various metabolic processes of the economy.

The development in the hands of Duchenne and Erb and Remak of electrical diagnosis, together with the great advances in physiology and pathology of the nervous system, has afforded explanation for much that was previously incomprehensible and has given us powers of diagnosis which a few generations ago would have seemed almost magical.

Finally Pasteur and Koch, with the introduction of bac-

teriological investigation, opened the way to the discovery of the causal agents of a large group of infectious diseases. These discoveries, followed rapidly by the evolution of methods allowing of the clinical demonstration of many pathogenic microörganisms, afforded an early, exact, and positive diagnosis, on the one hand in conditions where previously the disease was recognizable only at a stage in which it had made inroads into the system so great as to be often beyond relief, as in tuberculosis, and on the other, in maladies the existence of which without these methods was to be definitely determined only after the onset of an epidemic, as in cholera, plague, and influenza. When one thinks of what the last quarter of a century has taught us with regard to tuberculosis, anthrax, tetanus, diphtheria, typhoid fever, cholera, plague, dysentery, influenza, not to speak of the great group of wound-infections, we may begin to realize what bacteriological methods have done for diagnosis—how many diseases have been cleared up—how many symptoms have been explained.

In like manner Laveran, with the discovery of the parasite of malarial fever, did much to bring certainty and precision into a field in which many had gone astray, while opening the way for the important observations of Theobald Smith and all the knowledge which we have gained in recent years with regard to the hematozoa of man and animals.

As a direct result of the introduction of bacteriological methods, the study of the manner of action of infectious agents and their toxic products upon the animal organism, as well as of the powers of resistance of the economy against infection, has given us, with the discovery of specific agglutinines and precipitines, diagnostic methods of the greatest value, not only for the recognition of various infectious processes, but for the identification of specific

sera, affording in particular a test for human blood destined (probably) to prove, when properly applied and interpreted, of great medico-legal value.

This is indeed a gain over our knowledge of one hundred years ago. In how many fields has the conjectural given way to the exact! At the end of the eighteenth century the diagnostic effort of the physician, unaided by instruments of precision or even by the simplest physical methods of auscultation and percussion, was directed toward the defection of gross anatomical changes. Today with our increased knowledge of anatomical, physiological, and pathological processes, with our growing insight into the chemical and physical features of vital activity, our duty no longer ends in the recognition of physical changes in organs, in the determination of the presence of a specific lesion or infection; it is further our task to search for the earliest evidence of disturbance of function, which may later lead to grosser, more evident change, to separate the physiological from the pathological, to estimate, as far as may be, the power of resistance of the different organs and tissues and fluids of the body to insults of varying nature, to determine the functional capacity of a given organ—its sufficiency or insufficiency. In addition to increasing opportunities in the field of pathological anatomy we find ourselves drawn further into the study of pathological physiology—and knowledge in the field of pathological physiology leads of necessity to power in functional diagnosis.

It must be acknowledged that with regard to many organs the determination of the limits of functional power and the estimation of the degree of impairment in disease are matters most difficult to appreciate, yet with improved methods and persistent research, progress is being made.

We are, after all, but beginning to realize a few of the possibilities before us, but even this is a step in advance

which holds out no little promise for the future and offers new and tempting opportunities for study and investigation.

At the end of the eighteenth century but three important, rationally conceived measures of prophylaxis had been practiced—the dietetic measure of protection from scurvy, the older inoculation and Jenner's great contribution of vaccination against small-pox. It was not, indeed, until the development of bacteriology that prophylaxis took its place as a scientifically exact branch of medicine. The recognition of the specific cause of many infectious diseases, the knowledge of the life-history of the pathogenic micro-organisms, the discovery of the portals through which they gain entrance to the animal economy, and the conditions under which infection occurs, have brought to us material powers to prevent and protect. The first great result of this new knowledge was the development of antiseptic surgery and all that it represents. But apart from this we have but to remember what has been gained by a scientifically evolved prophylaxis against tuberculosis and typhoid fever—to reflect upon how far cholera and plague have lost their terrors—to contemplate the brilliant results of the discovery by Ross and the Italian school of the life-history of the malarial parasites as manifested in the anti-malarial campaigns carried on in various regions by Koch, and in Italy by the Society for the Study of Malaria, a noble institution, of which our Latin brothers may well be proud, and lastly to look upon the beneficent and far-reaching influence of the recent work of Reed and Lazear and Carroll and Agramonte with regard to yellow fever, to realize what bacteriological and parasitological studies are doing for preventive medicine.

But beyond this external prophylaxis, the studies of the problems of immunity, beginning with Pasteur's inocula-

tions against anthrax in 1881, have given us, so to speak, an internal prophylaxis, a functional prophylaxis, if one will, in the possibility of producing a greater or less degree of individual immunity, such, for instance, as is now possible in diphtheria, cholera, plague, typhoid fever and dysentery.

The enforcement of scientifically planned and accurately deduced prophylactic measures has become to-day one of the main duties of the practitioner of medicine. It is as much the task of the physician nowadays to guard over the disposal of the sputa of his tuberculous patient, of the excreta of the sufferer from typhoid fever, or cholera, or dysentery, as it is to attend to the immediate wants of the invalid. How rapidly has the exact replaced the conjectural in this branch of medicine!

But while diagnosis and prophylaxis were being removed from the domain of conjecture to the field of exact observation, and reason, and research, while the possibilities of surgery were rapidly widening through the discovery of anesthesia and the introduction of antiseptic methods, medical treatment, until the last two decades, still remained largely empirical. The development of exact clinical methods of observation and the statistical tabulation of experience for which we are especially indebted to Laënnec and Louis, and their followers, gradually brought about, to be sure, many advances, while a large number of useful therapeutic agents introduced by the newly developed science of pharmacology, and exactly tested by improved methods of physiological study, added greatly to the armamentarium of the physician for the relief of symptoms. The power to combat disease specifically, however, remained much as it was at the beginning of the century. Mercury in syphilis, quinine in malarial fever, were the only specifics known to the medical world—and the action of these was unexplained.

The introduction by George Murray, less than fifteen years ago, of the treatment of myxedema and allied conditions by extracts of the thyroid gland, was a direct application of the results of physiological observation to the treatment of disease. If this gave rise to hopes of the possibility of obtaining like results from roughly obtained extracts of other ductless glands, which have hardly been fulfilled, yet the discovery was the first step toward the rational scientific therapy to which we are beginning to look forward to-day.

But a moment ago I spoke of the importance of the influence of the discovery of the causal agents of the infectious diseases upon the development of exact diagnostic and prophylactic methods. Great and impressive as these have been, yet the studies which have followed as to the manner in which these agents act upon the human organism, and of the powers of resistance which the body exerts against them, the investigation of the problems of immunity have opened out a far wider field. The early studies of Metchnikoff and Buchner and Nuttall were followed with rapidity by the epoch-making work of Behring and Kitasato and Roux with regard to tetanus and diphtheria. The diphtheria and tetanus antitoxins were not chance discoveries of empirically determined virtue, but true specific, therapeutic agents, the results of experiment scientifically planned and carefully prosecuted. Widespread investigations of the various phases of immunity, bacterial and cytotoxic, have given us in a few short years a mass of physiological knowledge, the full import of which is scarcely yet to be comprehended. Few things in modern medicine are more impressive than a survey of the work of the last twelve years done under the inspiration of Ehrlich.

Beside the antitoxins of diphtheria and tetanus and the power of producing a greater or less degree of immunity,

as has already been mentioned, by preventive inoculations against cholera, plague, and typhoid fever, we have come to possess a bactericidal serum of a certain value in combating the actual disease, plague, while the favorable influence of Shiga's anti-dysenteric serum seems to be undoubted. There is much reason to hope that the recently promised anti-crotalus serum of Noguchi as well as the anti-cobra serum of Calmette may prove to be real boons to humanity. But it is not alone in the production of specific anti-sera that the therapeutic value of the modern studies of immunity lies. There are signs which justify us in looking forward to the possible discovery of an explanation of the mode of action of substances long empirically used, knowledge the value of which may be readily appreciated.

When we consider these facts it is indeed easy to appreciate to what an extent the exact has driven the conjectural from this last field of medicine. A hundred years ago we were depleting and purging and sweating and bleeding according to theories often strangely lacking in foundation, the prevalence of which depended rather upon the individual force and vigor of the expounder than upon their intrinsic merit. To-day from the study of the pathological physiology of bacterial and cytotoxic intoxications, we are rapidly evolving scientific preventive and curative measures, while searching out the rationale and made of action of our older therapeutic agents.

But a few days ago, I happened to open a copy of Littré[1] bearing, by a curious chance, the date of 1889, and read "Médecine (mé-de-sin). 1°. Art qui a pour but la conservation de la santé et la guérison des maladies, et qui repose sur la science des maladies ou pathologie"—an essential

[1] *Dictionnaire de la langue française.*

modification of the definition of one hundred years before and indicative of the changes of a century.

To meet the manifold problems of to-day, the training of the physician must of necessity be very different from what it was a hundred years ago. The strong reaction which set in in the earlier part of the nineteenth century against philosophical generalization in medicine, the insistence upon a strict objectivity, all the more emphatic because of the prevalence of anatomical methods of research, have held very general sway. Medicine, no longer resting upon a basis of philosophical speculation, stands upon the firmer foundation of the exact natural sciences. Almost from the beginning the student of to-day is taught methods, where a hundred years ago he was taught theories. The enormous expansion of the field which must be covered has led naturally, not only to an ever increasing specialism, but to the fact that the course of study which is regarded as properly fitting the physician for practice is reaching backward farther and farther into the earlier years of his school training. On the other hand, in this country at all events, there is heard a common cry that the academic medical training is extending over into years which should be given to practice; that the expense and duration of a medical education, so-called, will soon be such as to shut out from the profession many a man who might be a useful physician and perhaps a valuable contributor to the world's knowledge. To remedy this it is advised that the prospective student of medicine should be led from the earliest stages of his training through the paths of exact research into the domain of the natural sciences to the greater or less exclusion of the classics—the old-time humanities, the study of which, useful as it may be from a standpoint of general mental training, is believed by many to be time wasted in the education of the student destined for a scientific career.

But there are not wanting voices which question the wisdom of the full extent of some modern tendencies. May the affectation of too strict an objectivity bred though it may be of a wholesome skepticism, the more general cultivation of the natural sciences to the exclusion of the humanities, the search for facts and facts alone, circumscribe the powers of synthetical reasoning without which the true meaning of many an important problem might pass unnoticed? May they perhaps tend to smother the development of minds capable of grasping large general problems? Do the tendencies of the times justify the epigrammatic observation of a recent French author: "Autrefois on généralisait avec peu de faits et beaucoup d'idées; maintenant on généralise avec beaucoup de faits et peu d'idées"?[1]

That the cultivation of a strict objectivity in research has materially impaired our powers of reason—that the exact methods, which are largely responsible for the enormous advances of the last fifty years in all branches of medicine, have bred a paucity of ideas, I am not inclined to believe, despite the seductive formula of our Gallic colleague. But that when in the period of so-called secondary education it is proposed to *substitute* the study of the natural sciences for a good training in the humanities, there is danger of drying-up some of the sources from which this very scientific expansion has sprung, seems to me by no means impossible. The study of the classics, an acquaintance with the thoughts and the philosophies of past ages, gives to the student a certain breadth of conception, a stability of mind which is difficult to obtain in another way. A familiarity with Greek and Latin literature is an accomplishment which means much to the man who would devote himself to any branch of art or science or history. One

[1] Eymin, *Médecins et Philosophes*, 8°, Lyon, 1903-4. no. 4.

may search long among the truly great names in medicine for one whose training has been devoid of this vital link between the far-reaching radicles of the past and what we are pleased to regard as the flowering branches of to-day. Greek and Latin are far from dead languages to the Continental student. They are dead to us because they are taught us as dead. With methods of teaching in our secondary schools equal to those prevailing in England and the Continent, it would be an easy matter in a materially shorter period, to give our boys an infinitely broader education than they now receive. There should be much less complaint of time wasted, much less ground for suggesting the abandonment of the study of branches which are invaluable to any scholarly-minded man.

The assertion that the time spent in the study of the humanities results in the end in the encroachment of the academic training upon a period which should properly be given to one's life-work is, it seems to me, often based on an old idea—founded all too firmly, alas, on methods that yet prevail in many of our medical schools—that with his degree in medicine the student has finished a theoretical education, that he must now spend five or ten years in acquiring experience—at the expense, incidentally, of the public—before he can enter into his active life; that, therefore, unless some other branches of early instruction be sacrificed to courses leading more directly to medicine, so that he may enter upon his strictly professional education at a period considerably earlier than is now the case, the physician of to-morrow will become self-supporting only at a period so late in life as to render a medical career impossible to other than those well supplied with the world's goods. With proper methods of instruction this is a wholly false idea. Under fitting regulation of our system of medical training, with due utilization of the advantages

offered by hospitals for clinical observation, the experience necessary to render a man a safe and competent practitioner should not only be offered, but required for a license to practice; and even if the length of the strictly medical curriculum be extended one or two years beyond that which is at present customary, it will not be time lost. If one but look around him he will find, I fancy, that few men who have had such a training wait long before finding opportunities for the utilization of their accomplishments; the public in most instances soon recognizes the man of true experience.

But there is yet another side of the question which has hardly been sufficiently emphasized, a side of the question which must come strongly to one's mind when one considers the general education of many of the men who are entering even our better schools of medicine, a point of view which has been especially insisted upon by a recent French observer. A large part of the success and usefulness of the practitioner of medicine depends upon the influence which he exerts upon his patients—upon the confidence which he infuses—upon his power to explain, to persuade, to inspire. It can scarcely be denied that these powers are more easily wielded by the man of general culture and education than by one of uncouth manner and untrained speech however brilliant may be his accomplishments in the field of exact science. I can do no better than quote the words of Professor Lemoine: "C'est qu'en effet l'action morale qu'il peut exercer sur le malade, et qu'il exerce d'autant plus qu'il est supérieur par son intellectualité est un des principaux éléments de guérison. On guérit par des paroles au moins autant que par des remèdes, mais encore faut-il savoir dire ces paroles et présenter une autorité morale suffisante pour qu'elles entraînent la conviction du malade et remplissent le rôle suggestif qu'on

attend d'elles. Ne fut-ce que pour cette raison, je me rangerai parmi ceux qui demandent le maintien d'études classiques très fortes comme préparation à celles de la médecine, car le meilleur moyen de rehausser le prestige due médecin c'est encore de l'élever le plus possible au dessus de ses contemporains."[1]

These words express, it seems to me, a large measure of truth. May it not be that in the tendency to the neglect of the humanities we are taking a false step? May it not be that if, on the other hand, we teach them earlier and better, we shall find in the end that no essential time is lost, while we shall gain for medicine-men not only with minds abler to grasp the larger and broader problems, but with materially fuller powers for carrying on the humbler but no less important duties of the practitioner of medicine?

In that which I have just said I have touched upon the necessity of the requirement of a considerable amount of clinical experience as an essential for the license to practice medicine. To meet the enormously increased demands of the present day, medical education has become, of necessity, much more comprehensive, and must therefore extend over a longer period of time. The methods of research, anatomical, physical, chemical, which the student must master, the instruments of precision with which he must familiarize himself, are almost alarmingly multifarious; and experience in the application of these methods and in the use of these instruments demands increased time. Many of these proceedings, it is true, the physician will rarely

[1] Indeed the moral influence which he (the physician) is capable of exercising upon the patient and which he exercises to an ever increasing degree with his intellectual superiority, is one of the most important of therapeutic agents. One heals by words at least as much as by drugs, but one must know how to *say* these words and to exercise a sufficient moral authority, that they may bring conviction to the patient and carry the full weight of suggestion which is intended. Were it but for this reason I shall range myself among those who demand the maintenance of extensive classical studies as preparation for those of medicine, for the best means to uphold the prestige of the physician is still to raise him as far as possible above his contemporaries. *Congrés français de médecine,* VI Session, Paris, 1902, 8°, t. II, p. xli.

be called upon to use personally in practice, for such measures must in great part be carried out by special students or in laboratories provided by the Government. Nevertheless with their significance and value he must be familiar—familiar from personal observation and experience.

But after all there are few diagnostic signs in medicine, and not so many of the improved methods of clinical investigation yield diagnostic results, while to familiarize one's self with methods and instruments of precision is a very different matter from acquiring real experience and skill as a diagnostician or a therapeutist. It is only by gathering together and carefully weighing all possible information that one is enabled to gain a proper appreciation of the situation and to approach a comprehension of many conditions of grave import to the patient. And in forming a sound judgment with regard to these vital questions, that which comes from experience in the close personal observation of the sick is far the most important element. Bedside experience constitutes to-day, as it always has, and always will, the main, essential feature in the training of the physician. But this experience, if it is to bear its full fruit, must be afforded to the student at a time when his mind is still open and receptive and free from preconceived ideas—under conditions such that he may be directed by older trained minds into proper paths of observation and study, for few things may be more fallacious than experience to the prejudiced and the unenlightened.

That such experience may be freely offered to the student there is a grave necessity for a more general appreciation by institutions of medical training as well as by the powers in control of public and private hospitals and infirmaries, of the mutual advantages to be gained by a cordial coöperation. It must be acknowledged that, in this

country at least, despite the cultivation of improved methods of clinical investigation, there still prevails in the mind of the public the perverted idea that this bedside observation, this application of new methods of research and study are for the advantage of the student or in the interest of general science rather than for the benefit of the sufferer himself. It must further be recognized that a wholly mistaken conception of the true function of a hospital is widely prevalent. It is all too common to see large and ornate institutions with every arrangement for the comfort and even luxury of the patient, with a medical staff utterly insufficient in number or training to study properly the individual case, not to speak of carrying on scientific investigations. The service, usually under the direction of a busy driven practitioner with barely time to make a short daily visit—large wards under the direct control of one or two young men whose time is wholly occupied by routine work—every care taken for the present comfort of the patient—little provision for enlightened study or treatment of his malady—no opportunities for a contribution on the part of the institution to the scientific progress of the day. Better far for the sufferer were he in the dingy ward of an old European hospital where he might be surrounded by active, inquiring minds recording the slightest changes in his symptoms, ever ready to detect, and as far as the power in them lies, to correct the earliest evidences of perversion of function. What our hospitals need is men, students, whether or no they have arrived at the stage in their career—which, after all, is but a landmark, not a turning-point—that entitles them to the right of independent practice, the enthusiastic, devoted student who, in watching and studying the patient, is contributing alike to the interests of the sufferer, the hospital, and himself.

The three main functions of a hospital—the care of the

sick, the education of the physician, the advancement of science—are not to be met alone by building laboratories and operating-rooms and lecture-halls, by furnishing the refinements of luxury to the patient, useful adjuvants though these may be. What the hospital mainly needs is men, men to study and think and work—*students of medicine.*

It cannot be denied that in this respect we in America are behind our cousins of the Old World. Despite our many honorable achievements, the part which we are taking in the modern study of the physiology of disease is still not what it should be.

Ere long we must come to realize that our duty to the sick man consists in something more than to afford him that which most sick animals find for themselves—a comfortable corner in which he may rest and hide from the world; that our duty to the public is to give them as physicians, men of the widest possible general training, ready to enter upon independent practice with an experience sufficient to render them safe public advisers; that our duty to ourselves is to miss no opportunity for the study of pathological physiology at the bedside of the patient; that the accomplishment of these ends depends in great part upon the appreciation by our universities and hospitals of the mutual advantages of coöperation in affording every opportunity for the scientific study of disease while offering to the patient the privileges of enlightened observation and care.

But there are everywhere signs of a future rich in achievement. An improving system of medical education, the increasing opportunities for scientific research offered as well by the generosity of private citizens as by the wisdom of state and national governments, the community of effort which results from closer fellowship among students

of all nations, are omens of great promise. The remarkable developments of the last twenty years in all branches of the natural sciences have brought a rich store of suggestion and resource for application in our laboratory, which is at the bedside of the patient. Let us look to it that our clinical methods keep pace with those which are yielding so abundant a harvest in these neighboring fields of scientific research.

SOME FUNDAMENTAL PROBLEMS IN OBSTETRICS AND GYNECOLOGY

BY JOHN CLARENCE WEBSTER

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MARKED as have been the advances during the modern scientific era in our knowledge of woman in respect to her anatomic and physiologic peculiarities, her special diseases, and the treatment thereof, many problems yet await solution, some of which are chiefly of scientific interest, others of therapeutic importance.

In complying with the request of the organizers of this great Congress, I have fully realized the seriousness of the responsibility which I have assumed in restricting myself to the topics which I have selected for your consideration. I have avoided all reference to matters pertaining to the treatment of disease, believing that the presentation of certain fundamental scientific problems would be more in keeping with the aims of this convention. I have also deemed it best to confine myself to a few topics of particular interest or importance, rather than to wander discursively over the entire scientific field open to the gynecologist. Your attention is, therefore, directed to the following subjects:

1. The determination of sex.
2. The structure of the ovary.
3. The functions of the ovary.
4. Antagonism between maternal organism and ovum.
5. Functions of the placenta.

Determination of Sex

From the time of Hippocrates to the beginning of the eighteenth century, about five hundred theories relative to the question of sex-determination had been advanced. During the last two hundred years this number has been considerably increased. At the beginning of the twentieth century, it must be frankly admitted that the problem of sex-determination in the higher vertebrates generally still remains to be solved. The most important observations and experiments bearing on the question have been made during the last fifty years, and from a study of these it would appear that the most exhaustive researches in comparative and experimental embryology and physiology will be necessary before the difficulties of the subject can be elucidated. The data furnished by the study of human beings are scanty and of little value. Most of the statements which have been made are speculative in nature, or of doubtful accuracy. Certain it is also that all attempts to regulate the production of sex in the human fetus in utero have met with failure.

In many countries the belief has long been current that the sex of the human fetus could be modified during a greater or less period of its uterine life. Now we know that the sex is fixed at least by the beginning of the second month, for at that time the microscope can distinguish ovarian from testicular structure. It is, therefore, scarcely credible that any reversal of sex can be brought about after this period by any conceivable combination of influences.

We must, indeed, look to conditions existing during the first month of gestation, or at the time of the meeting of the spermatozoön and ovum, or to influences affecting either or both of the latter before conception, in order to find explanation of sex-determination in the human embryo. Those who believe that both sperm and ovum share in the production of sex refer to the various statistics giving the relationship of the parental ages to the sex of the offspring. Hofacker in 1823, and Sadler in 1830, independently stated, as the result of an analysis of about 2000 births, that when the father is the older the offspring are preponderatingly male; while if the parents be of the same age, or if the mother be older, there is a larger percentage of female children. This generalization, termed the law of Hofacker and Sadler, has been the subject of much debate, having been upheld by some and denied by others during the last 70 years.

Those who believe that the influences determining sex belong to the ovum entirely find no evidence to support them from a study of the highest forms of life, though there is strong corroboration from investigations made among lower forms. Thus in cases of parthenogenesis it is evident that the influence of a male paternal element must be entirely eliminated in the determination of sex. B. S. Schultze advanced the view that there are two kinds of ovums, one of which may give rise to males, the other to females, but there has been no proof of such a differentiation in the higher forms of life. In several low organisms, however, it appears that these two varieties (of ovums) exist. Thus Korschelt describes two kinds of ovums in the ovaries of the worm Dinophilus opatris; one of large oval shape, developing into females, the other small and round, becoming males.

With regard to the determination of sex by influences

brought to bear either upon parents, the sexual elements, or embryos, many observations have been made, but trustworthy conclusions may be derived only from the study of comparatively low organisms. The influence of nutrition is thus considered of great importance in determining sex. As illustrations may be noted the variations in the sex of frogs associated with changes in the nutriment supplied to the young tadpoles. Yung found that when the latter were left to themselves the percentage of females was slightly in the majority, but when very rich food was supplied, 92 females to 8 males in every hundred were produced. In the case of bees it seems evident that the influence which decides whether the offspring of the fertilized ovums shall become queens or workers is the nature of the food-supply. Rich and abundant diet develops queens; plain and scanty food leads to the production of workers, in whom reproductive organs are undeveloped. Very interesting observations have been made upon plant-lice or *aphides*. In the warm months when food is plenty they reproduce by parthenogenesis, the offspring being entirely female. When colder weather and scantier food appear there is sexual reproduction and an offspring of males. In the artificial life of a well-kept greenhouse, these phases may be repeated at the will of the observer, by varying the nutrition. So far as the temperature is concerned, Geddes and Thomson state that experiments point to the conclusion that favorable conditions tend to femaleness and extremes to maleness of offspring. As regards higher forms of life, it is impossible to estimate the importance of nutrition, temperature, etc., in the determination of sex, while as regards mammalians this field of inquiry is as yet entirely speculative.

From what is known of the early embryology of many invertebrates and some of the lower vertebrates, it would appear that their early embryonic life is one of indeter-

minate character so far as sex is concerned, during which various conditions, *e. g.*, nutriment, temperature, moisture, light, may act so as to produce maleness or femaleness according to their abundance or deficiency. Whereas, in the higher vertebrates, the period of embryonic sexual indeterminates (if any) is very short, and so far as is known no influence can be brought to bear on the ovum which can in any way determine sex. The mammalian ovum developing in the uterus seems to enjoy such a sheltered existence that it is impossible to conceive that changes may be induced in its environment comparable to those which have been experimentally introduced in the study of ovums and embryos of low vertebrate and invertebrate forms of life. Indeed, it would seem that the most satisfactory theory of sex-determination in the higher vertebrates is that which supposes the existence of two forms of ovums—one destined to maleness and the other to femaleness, though it is impossible to establish any such differentiation by microscopic study or chemic analysis. The elaborate work of von Lenhossek, recently published, strongly favors this view that sex is fixed in the ovum before the spermatozoön fertilizes it. If such be the case it is quite futile to expect that any alteration may be brought about by dietetic or other influences made to affect the human female either before or during gestation.

In this connection it is interesting to refer to the question of the occurrence of true hermaphroditism in the human species. Many hold that this has never been demonstrated. Nagel, for example, states that it probably cannot exist, and holds that the ovary is never found with the testes in cases of so-called hermaphroditism. Recently, however, Sarré has described the case of an individual with the external configuration of a woman, who possessed a well-developed imperforate penis. On making a rectal ex-

amination, two small bodies, each the size of a pigeon's egg, could be felt in the left half of the pelvis, while in the right inguinal canal an ovoid body was found. An exploratory incision was made over the latter and the swelling removed, along with a smaller mass attached to it. Microscopic examination proved these to be testicular structure and epididymis. Another small mass near the testicle was also examined and found to be ovarian tissue. A Fallopian tube and a structure resembling the vas deferens were also present. Sarré believes that, with the exception of another case described by Ziegler, all other records of true human hermaphroditism are very doubtful, though he thinks it has been clearly demonstrated in some lower mammals, *e. g.,* the pig.

The Structure of the Ovary

In spite of the immense amount of investigation to which this organ has been subjected, many points in its development, normal and pathologic histology, still require elucidation. It is generally agreed that the ovary is developed from epiblast and mesoblast on the inner surface of the Wolffian body. The epiblast, a specialized portion of the celomic lining, very early forms a mass consisting of several layers of cells, the germinal epithelium. In the deepest portions certain of these cells increase in size, giving rise to the primordial ovums. The latter are all formed previous to birth. As the epiblast layer increases in thickness, processes of the underlying mesoblast of the Wolffian body extend outward among the germinal cells, forming a network-like stroma, in the meshes of which lie primordial ovums, frequently surrounded by germ cells. Regarding the formation of the primary follicle, there are differences of opinion. Most believe that the germ cells arrange themselves around the

ovum forming the primary follicle, in later life proliferating to form the membrana granulosa. In 1878, Foulis, of Edinburgh, contended that the cells surrounding the primordial ovums are derived from connective tissue, and lately Wendeler and Clark have advocated this view. The latter has pointed out that the cells are usually spindle-shaped in the early stages and that frequently primordial ovums are found without any special layer of cells surrounding them. Kölliker stated that the follicular epithelium was derived from Wolffian epithelium, but this view has received little support. Regarding the changes between birth and puberty, we do not possess exact information. It is believed that during this period more than half the primary follicles disappear, though the manner and reason of the disappearance are not clear. The period of puberty is characterized by the development of Graafian follicles, which rupture gives rise to the peculiar structure of the corpus luteum. In some cases this phenomenon may be noted months before the external signs of puberty are detected and occasionally years previously. The explanation of these variations is not known. Some degree of development of the ovum seems to be a normal occurrence in the pre-puberty period. Stevens has recently described these as follows: The follicle and contained ovum mature to a certain extent. The single layer of flat cells surrounding the dormant ovum proliferates and becomes somewhat cubical, several layers being formed—membrana granulosa. The ovum increases and is surrounded by a discus proligerus; there is also a zona radiata and liquor folliculi. At its greatest the follicle measures about $.8 \times .7$ mm.; the ovum, $.1 \times .095$ mm. The tunica fibrosa is well marked, and resembles the ovarian stroma, being somewhat more vascular. Sometimes excessive liquor folliculi collects. Retrograde changes gradually develop. The

ovum is invaded by cells, which are apparently phagocytes, derived probably from the membrana granulosa. Their protoplasm is vacuolated and they do not resemble leukocytes. Necrobiosis gradually develops, and most granulosa cells disintegrate. The tunica fibrosa gets many capillaries and the connective-tissue cells multiply. On the inner surface a hyaline layer of fibrin forms, in which new connective tissue develops. The follicle gradually shrinks, leaving a small scar area. It thus appears that the prepuberty changes in the follicles differ from those in adult life in the following particulars; the ovum does not reach such a large size. The wall of the follicle external to the membrana granulosa does not present a two-layer arrangement; there is no rupture of the follicle; there is no formation of a corpus luteum; the ovum is invaded by phagocytic cells. In adult life, also, it is to be noted that, beside the follicles which rupture, there are others which may develop to a certain extent and then undergo retrograde changes before rupture occurs. The ovum may increase, a yellow body may form, owing to the development of lutein cells in the theca interna. Then the ovum and surrounding epithelium degenerate and are absorbed, along with the liquor folliculi. The explanation of such a process is not always certain. In some cases it appears to be due to chronic inflammatory changes in the ovary, but it is probably also due to other causes of which we are ignorant.

Regarding the bursting of the follicle there is a difference of opinion. Most authorities hold that the ovarian tissue, being greatly thinned at the most projecting point, is gradually ruptured by the increase in intrafollicular pressure resulting from the accumulation of liquor folliculi. Nagel, however, holds that owing to an increase in the thickness of the inner layer of theca folliculi, to the swell-

ing of its cells with lutein particles and to its becoming arranged in a wavy manner, pressure is made on the follicle contents from without, and that they are forced in the direction of least resistance, viz., outward toward the surface of the ovary.

Clark holds that rupture is due to changes in the circulatory conditions in the ovary. Owing to the marked engorgement of the organ, tension is increased and the follicular contents are forced to the surface. The vessels lying external to the follicle at the bulging portion are compressed, and consequently necrosis and disintegration of the tissue take place. *Pari passu* with the development of the lutein cells there is fatty degeneration in the cells of the stratum granulosum and in those of the discus proligerus. This enables the ovum to escape easily from the cells surrounding it.

The formation of the corpus luteum has given rise to considerable discussion. Some workers still hold firmly that it is a derivative of the membrana granulosa. The majority hold, however, that it is developed from the inner part of theca folliculi, which is regarded as a cellular layer of the connective-tissue stroma of the ovary.

Of great interest is the observation recently made by Stoeckel, Pick, and others, that, occasionally, corpus luteum cells may not undergo their normal growth and retrogression within the limits of the follicle, but may wander outward into the ovarian stroma and even undergo atypic proliferation. I have occasionally noted this wandering, though not to a great distance; in some instances the cells contained abundant dark pigment apparently derived from blood which had been effused into the cavity of the follicle. The explanation of these irregular phenomena is quite uncertain, and is deserving of careful investigation.

Another interesting histologic appearance has been de-

scribed in recent years by Pels Leusden, Schmorl, and others, viz., small localized areas of decidua-like cells in the ovary in some cases of uterine pregnancy. I have recently examined ten specimens in my museum, and have found these changes in four ovaries. In one a single area was found in a complete section of the ovary; in the others, two were found at different portions and varying in size. In each instance the areas were situated in the cortex, at or near the surface, sometimes projecting slightly from the latter, sometimes extending some distance into the cortex. The cells in these areas bear the closest resemblance to the uterine decidua in normal pregnancy, presenting similar variations in size and shape. The line of demarkation from the surrounding ovarian stroma is always well marked, giving the impression that the two tissues are distinct. Usually these areas contain dilated capillaries which are not found in the neighboring unchanged ovarian stroma.

I have never found such areas in ovaries removed from non-pregnant women. What is the explanation of these changes? It might be suggested that they are peripheral portions of the theca interna of the ripening Graafian follicles or of a corpus luteum. Serial sections show, however, that this is not the case. The large cells are undoubtedly of connective-tissue origin, but their definite localization suggests some special characteristic which makes the cell capable of undergoing the same genetic reaction which is ordinarily found in the uterine and tubal mucous membrane when pregnancy develops in relation to these tissues.

Tentatively, I advance the view that these areas represent displaced portions of Müllerian tissue, which have become attached to the surface of the ovary in early embryonic life. Occasionally, I have found in the substance

of such an area a gland-like space lined with columnar or cubical epithelium. The latter may, of course, be simply a derivative of the surface germinal epithelium, but it may indeed represent included Müllerian epithelium.

It is possible that the special genetic reaction in these areas may sometimes determine the imbedding and development of a fertilized ovum in the ovary, and if the opinion that they are Müllerian in origin be correct, it is not unlikely that all cases of pregnancy in ovarian tissue may still serve to support the dictum which has been widely believed in recent years, viz., that imbedding and development of the fertilized human ovum in the earliest stages can only take place in a tissue capable of undergoing a special genetic reaction, and that this tissue is in all cases Müllerian in origin. While the proof of this is impossible, all *a priori* evidence is in its favor. Those who attempt to overthrow the hypothesis certainly undertake a heavy task in trying to establish an exception to the uniformity of performance of one of the most complex and highly specialized functions in the human body. The indication of the genetic reaction is decidual transformation, and this is normally found only in the mucosa of the corpus uteri, where indeed it occurs in all cases of pregnancy, whether the latter be uterine or ectopic. In certain cases we know that decidual changes may occur in other portions of the Müllerian tract, most frequently in the fallopian tubes, a fact which probably helps to explain the occasional occurrence of pregnancy in the latter.

With regard to ovarian gestation, in the specimens which have been most fully studied, viz., those of von Tussenbroek, Thompson, and myself, it is true that no definite decidual layer is found in the wall of the gestation sac. Though von Tussenbroek, in her first description, mentioned a decidual layer, she afterward stated that this was

an error, the cells being in reality lutein cells of the corpus luteum. The final account is in the main correct, but she cannot deny the possibility that some of the large cells were decidual. However, admitting that no decidual cells are found in specimens as advanced as those mentioned, we do not know that they were not present at an earlier stage, when the ovum was very small. One of the small ovarian decidual areas to which I have referred would very soon disappear as a result of the outward pressure of the expanding ovum, as well as of the phagocytic action of the trophoblast, if there be no more tissue capable of undergoing decidual changes, and it is quite evident that the ovarian stroma proper does not tend to undergo this transformation.

Even in tubal pregnancy, in which decidual changes are always present in the early stages, there may be a marked disappearance as pregnancy advances, the production of cells being evidently much poorer than in the uterine mucosa in normal pregnancy, though in the latter there is a considerable range of variation. In my own recently described specimen of ovarian gestation I believe that I have demonstrated a few scattered groups of decidual cells in the ovarian stroma near the inner wall of the gestation sac.

For several years I have held the belief that decidual transformation is peculiar to the Müllerian tract. The occasional finding of the small areas of decidua-like cells in the ovary in uterine gestation has been regarded by several writers as a proof that other tissues may also undergo the change. From what I have already stated it remains to be proved that these areas are not Müllerian in origin. The occasional blending of Müllerian and ovarian tissues has been abundantly proved, both by macroscopic and microscopic demonstration. Take, for instance, the relation-

ships of the ovarian fimbria. In some cases its outer end may not reach the ovary, sometimes it may just touch it; sometimes its tip may be imbedded in the ovary; sometimes a considerable extent of the fimbria may lie against the ovary or adherent to it; in some cases there may be a break in its continuity, so that a small outer portion may lie close to the ovary detached from the main part. Marchand has directed attention to the early close relationship between the tubal epithelium and that covering the surface of the ovary, and has pointed out that they are one and the same surface. He believed that in some cases the line of demarkation, instead of being at the end of the ovarian fimbria, might reach over to the lateral portion of the ovary and that from it processes might extend into the cortex of the ovary. The observations of De Sinety and Melassez, in 1878, seemed to establish the correctness of such a view. Other studies, especially those of Whitridge Williams, leave no doubt as to the occasional extension of Müllerian tissue into the ovary. It need not, therefore, be a matter of surprise that small areas are occasionally found in the ovary of pregnancy, presenting the appearance of decidual changes in the connective tissue of the uterine mucosa.

It must also be mentioned that small localized decidual nodes have also been found in the broad ligaments. I believe that these are also derived from displaced portions of Müllerian tissue, which are quite common, especially in the upper portion of the broad ligaments. Similar areas have also been found under the peritoneum of the pregnant uterus, but this cannot be considered as at all remarkable, since there is no doubt as to the Müllerian nature of the uterus. Rarely they have also been found behind the peritoneum of the pouch of Douglas, and it is not unlikely that even in this neighborhood may be found small detached Müllerian fragments displaced backward in early embryonic life.

In describing these small decidua-like areas it must be remembered that somewhat similar appearances may sometimes result from chronic inflammatory changes in the peritoneum, associated with inclusion of the endothelium and proliferation of the latter. The large cells produced in this manner are usually closely packed and suggest masses of epithelium rather than the looser arrangement of multiform anastomosing cells found in the connective-tissue decidual areas.

The Functions of the Ovary

In addition to furnishing the ovums, it has long been recognized that the ovary exercises an important influence on the body, though the nature of the influence and the changes induced by it have been and still are unknown. Recently, various workers have suggested that the ovaries are ductless glands, whose internal secretion affects general metabolic processes.

Several years ago, it was noted that in many cases of osteomalacia the disease could be checked by removal of the ovaries. Fehling, a pioneer in this line of work, made a careful study of the urine in his cases, but gained no information as to metabolic changes by comparing its condition before and after operation.

In 1894 and 1896, Neumann stated that removal of the ovaries in this disease exercised a marked effect in lessening the excretion of magnesium, calcium, and phosphorus, as well as diminishing proteid disintegration. Later, Neumann and Vas experimented on normal female animals, and found that Merck's ovarian tabloids, even in large doses, did not appreciably alter the quantity of nitrogen or phosphorus in the urine. They found, however, that there was an increased excretion of these when their own preparation of cow's ovary was administered. They also

noticed no pronounced alteration in the phosphorus excretion after removal of ovaries from animals. When ovarian tabloids were given to spayed animals, there was increased excretion of calcium and phosphorus, and less marked nitrogenous excretion.

The experiments of Curatulo and Tarulli, in 1895, have attracted a good deal of notice. They fed bitches on a regular diet until there was a uniform average daily excretion of phosphorus and nitrogen. The ovaries were then removed, and thereafter the excretion of phosphorus was much diminished. They concluded that the ovaries produced an internal secretion, of unknown nature, which influenced the oxidation of organic substances containing phosphorus which enter into the structure of bone. In accordance with their view, it has been widely believed that the beneficial influence of the removal of the ovaries in osteomalacia was due to the retention of more phosphorus in the system and its deposition in the bones in the shape of phosphates.

In 1899, Falk repeated these experiments, but did not arrive at the same conclusions. After removal of the ovaries in two bitches, he noticed no difference in the amount of phosphorus excretion.

Moreover, recent investigations regarding the source of the excreted phosphorus tend to lessen the value of these experiments. They appear to show that much of the phosphorus is derived from nucleoproteid in food, and it is possible that the increased excretion after the administration of ovarian tissue or extract is thus explained. Curatulo also holds that the ovarian secretion favors the oxidation of carbohydrates and of fatty substances, and explains the tendency to corpulency when the ovaries are removed in the reproductive period of life, or after the menopause, as due to the loss of the ovarian secretion.

The results of various experiments in the administration of ovarian tissue or extract in the human female have in no way helped to throw light on the subject under consideration, nor have they tended to uphold the theory of an internal secretion. The use of the gland in various diseased conditions of the pelvis has not served to give to it any definite therapeutic value. Neither has its administration at the time of the climacteric served to ameliorate or dispel the troubles incident to that period. Results, good, bad, and indifferent, have been published, leading strongly to the conclusion that in the cases observed only the same variations in clinical features have been recorded which may be recognized when any group of menopause cases is studied uninfluenced by any medication.

Whatever the influence of the ovaries may be, it seems to be established that they affect the organism through the circulation and not through the nervous system, and thus support is given to the theory of an internal secretion. Many experiments have been made in transplanting the ovaries of animals from their normal situation to some other, *e. g.*, the peritoneum, subcutaneous tissue, muscles, etc. While after transplantation some of the ovarian tissue usually necroses, the remainder generally lives and continues to functionate, ovums continuing to develop, ripen, and even to escape from follicles. When this activity continues, no matter where the ovary is placed, the genitalia and mammae remain well developed just as though the organ is in its normal position.

The Rôle of the Corpus Luteum

Recently the view has been advanced that the internal secretion of the ovary is produced by the corpus luteum, and that the latter structure exercises very important functions in the female organism. The late Gustav Born, of

Breslau, was the first to bring forward the hypothesis, stating that the particular function of the corpus luteum was to favor the imbedding and development of the fertilized ovum in the uterine mucosa.

Ludwig Fraenkel has recently published an elaborate paper in which he states his belief that the internal secretion produced by the yellow body keeps up the nutrition of the uterus during reproductive life, leads to the phenomena of menstruation, and favors the imbedding and development of the fertilized ovum. Uterine atrophy and amenorrhea are brought about when no corpora lutea are found. Thus are explained the conditions normally found before puberty and after the climacteric. The facts upon which this remarkable hypothesis is based are derived mainly from experiments carried out on rabbits, since in these animals the time of occurrence of the various stages of gestation, following insemination, are fairly accurately known.

In endeavoring to determine the influence of the ovary on implantation of the fertilized ovum, Fraenkel removed the ovaries from thirteen rabbits, one to six days after copulation. Later these animals were killed, and in no instance was an ovum found in the uterus. In another series only one ovary was removed, and this did not interfere with gestation. It seemed, therefore, that implantation had been prevented by removal of both ovaries.

In another series of rabbits the ovaries were removed after implantation of the ovums, and it was found that their development ceased. though they were not expelled from the uterus.

Similar results were obtained when, instead of removing the entire ovarian tissue, the corpora lutea were destroyed with a cautery. It was found that development of the ovum might continue if only one corpus luteum was

left in the ovary. When the ovaries were transplanted, destruction of the ovum occurred, though after some delay. After burning the corpora lutea from the ovaries, it was found that the uterus was much atrophied in two weeks.

This physiologic interpretation of the function of the corpus luteum is worthy of the highest consideration. Hitherto, anatomic explanations have been chiefly prevalent. Thus, it has been considered as forming an extra protective covering to the ripening ovum, as a plug to check hemorrhage after bursting of the follicle, and as a kind of splint steadying the tissues during the process of healing. Clark has pointed out that it is evidently associated with a method of repair, which leads to little formation of connective tissue, and has well stated that if the ruptured follicles were healed by the ordinary method, the ovary would be converted into a mass of connective tissue, which would render the escape of ovums increasingly difficult.

On the other hand, Fraenkel and others who adopt the physiologic interpretation, emphasize the well-known structural resemblance of the fully-formed corpus luteum to a ductless gland, since it consists of rows of large epithelioid cells—the lutein cells, arranged somewhat radially, strands of delicate connective tissue containing blood-vessels ramifying between the columns. Fraenkel holds with Sobotta and others that the yellow body is derived from the membrana granulosa, and that thus an epithelial origin is obtained for the cells of the glandular organ. I have already pointed out that many authorities hold that the corpus luteum is derived not from the membrana granulosa, but from the connective tissue external to the latter, while a considerable number hold that the membrana granulosa is itself of connective-tissue origin. If the latter view be correct, and the glandular nature of the corpus luteum be established, such a marvelous transformation of connective

tissue is without parallel in any other portion of the human body. But even if its origin be epithelial, it is equally remarkable and unique that a glandular function should be carried on during many years by a continued series of new formations in different portions of an organ.

In considering Fraenkel's hypothesis, various questions suggest themselves for investigation. If the corpus luteum causes the phenomena of menstruation, why is the latter function limited to the primates? Born has pointed out that in all animals in which there is a uterine insertion of the ovum there is a well-developed corpus luteum, whereas in all other animals the latter is either rudimentary or not developed at all. In all mammalians above the monotremes the ovum is implanted in the uterus and the corpus luteum is well developed. The absence of menstruation in the great majority of these must either be due to some peculiarity of the corpus luteum or to other unknown reasons.

If the corpus luteum presides over the implantation of the ovum through its internal secretion, does the latter influence the ovum by passing to it through the maternal tissues (where presumably it circulates) or is the ovum already influenced at the time it escapes from the follicle? Fraenkel's experiments seem to negative the latter hypothesis, for if the ovum reaches the uterus already charged with the secretion, destruction of the corpora lutea in the rabbit might not be expected to affect its implantation. It is therefore more reasonable to suppose that contact with the uterine mucosa in which the ovarian secretion circulates leads to the conditions which determine the imbedding of the ovum. From histologic studies it is now known that the implantation of the ovum in the mammalia occurs after certain changes have taken place in it, that in the vesicular stage there is a proliferation of the outer layer

of epiblast forming the trophoblast which has the power of attaching itself to the uterine mucosa, or absorbing the latter and burrowing into it. Is this power dependent upon the influence of a circulating ovarian secretion? Hitherto it has always been believed that these changes were possessed by the ovum itself, for in animals developed from ovums which find no resting-place in the body the development of the ovum does not depend upon the maternal organism.

It must, however, be believed that in the higher mammals, at least, some special complementary characteristic must be found in those areas of maternal tissue on which the ovum grows. In the human female, for example, as I have already pointed out, a particular portion of the Müllerian tract, viz., the mucosa of the corpus uteri, is the normal seat of implantation. The normal occurrence of a decidual reaction in this area has already been noted. Is it possible that this peculiar change is brought about by the ovarian secretion and is a prominent indication that the tissues are favorable to the reception of the ovum?

Recently various authors have suggested a connection between abnormal conditions of the ovary or corpus luteum and aberrant developments of the ovum. Thus several cases have been described in which hydatidiform mole has been associated with disease in the ovary, especially cystic degeneration. Pick has recently made a careful study of a case in which excessive production of lutein tissue was found in the ovaries, and he regarded this condition as the cause of excessive chorionic development, leading to the formation of hydatidiform mole. In chorioepithelioma this author, Runge, and Jaffé have also described excessive production of lutein cells in the ovary, which they are inclined to consider as the cause of the chorionic growth. In several specimens of ovaries examined by Pick, Stoeckel,

Runge, and others, in addition to cystic changes in Graafian follicles and corpora lutea, collections of lutein cells were found scattered through the ovarian stroma. Careful study of a larger series of ovaries must be made before any positive statement can be made in regard to the association of changes in them with abnormal development of the ovum. It is certainly difficult to explain the occurrence of hydatidiform mole in a twin pregnancy by the the lutein secretion hypothesis. If over-production of the latter be the sole cause, it is strange that both ovums should not be similarly affected.

The Antagonism Between Maternal Organism and Ovum

For several years the idea has been steadily gaining ground that the maternal organism during pregnancy is very commonly affected by circulating toxic substances, and that many disturbances, both of major and minor importance, are caused thereby. This view has been chiefly prominent in recent investigations concerning the nature of eclampsia. Though little success has been obtained in the identification of specific toxins, there has been plenty of speculation as to their source and nature. The maternal organism has been considered the chief source of their production, the contribution of the ovum being generally regarded as of minor importance.

Recently, however, a new theory attributes to the latter a much more prominent rôle than has hitherto been suspected. In addition to the passage into the maternal circulation of the waste products of fetal metabolism, it is believed that there is a continual warfare between the chorionic layers of the ovum and the maternal tissues, that the proliferating and invading tendencies of the former are continually antagonized by the latter, and that a toxic

chorionic internal secretion is produced which is neutralized or destroyed by maternal influences.

In normal cases of pregnancy it is considered that there is established a kind of equilibrium between the ovum and maternal organism; that in some abnormal cases the ovum suffers as the result of predominant activity of the maternal elements, while in others the maternal organism suffers when the ovum is in the ascendant. In the former instance the ovum may be destroyed and abortion result; in the latter the mother may exhibit phenomena of various kinds, from the minor nervous and alimentary disturbances of pregnancy to such marked disorders as pernicious vomiting or eclampsia. This same theory would also explain the rapid growth of chorionic tissue after pregnancy, giving rise to chorioepithelioma malignum, as mainly due to some defect in the maternal factors which normally counteract the excessive proliferation of chorionic epithelium.

These newer lines of thought have followed close upon the establishment, by recent workers, of the exact histologic relationships between the human ovum and uterus. It has been demonstrated beyond doubt that the early ovum in its vesicular stage is characterized by a proliferation of its outer epiblastic covering forming a layer of cells, distinct from one another, known as the trophoblast, and that through the activity of this layer the ovum burrows into the superficial part of the uterine mucosa, where it becomes completely imbedded. The trophoblast continues to extend outward in all directions, lacunas appearing in it. Into the latter, blood finds its way from maternal sinuses which have been opened by the phagocytic activity of the trophoblast. The entire trophoblast is in this way converted into a sponge-like structure. The lacunas enlarge, and the trabeculas between them become smaller. The former are the forerunners of the permanent intervillous spaces of the

placenta, the latter of the villi. The trophoblastic cellular trabeculas are gradually penetrated by the mesoblastic layer of the chorion in which the terminal branches of the umbilical vessels carry on the fetal circulation. As soon as lacunas appear in the trophoblast a change takes place in the cells of the latter lining the lacunas. They appear to become fused into a continuous layer of nucleated protoplasm in which no cell outlines can be distinguished. This is the earliest stage in the formation of syncytium, and was regarded by Peters, in whose specimen it was demonstrated, as caused partly by the pressure of the maternal blood in the lacunas, partly by the influence of the blood-plasma; in some parts, also, blood-corpuscles appeared to become degenerated and to fuse with the trophoblastic cells.

As pregnancy advances, the syncytium rapidly increases so that it covers the entire chorion. The unaltered trophoblast cells subjacent to the syncytium form the layer universally known as Langhan's layer. Wherever the chorion comes into contact with the maternal decidua, evidence of invasion of the latter by the former is found, but it is chiefly noticeable at the site of the placental portion of the chorion, the decidua serotina. Here in the early weeks of gestation irregular extensions of syncytium may be found. They are chiefly noticed in the compact layer of the serotina, but are observed in the spongy layer, and even in the muscular wall. Portions undoubtedly extend into maternal blood sinuses, to whose walls they may become attached. Small portions of syncytium also may be carried away in the venous circulation. That this may take place throughout a considerable period of pregnancy is highly probable. Several authors hold that pieces of villi, comprising both epithelial and connective-tissue elements, may also be deported, though I have never observed this in normal specimens.

Whatever be the extent of the process no important anatomic lesions in the vessels of the lungs or elsewhere have been demonstrated to result from them. The chorionic fragments are very small and are probably rapidly disintegrated in the maternal blood. Their destruction is explained according to Ehrlich's now well-known hypothesis. The foreign fragments produce a substance which fixes them to the red blood cells, and which also enters the serum, forming an antitoxin, which tends to destroy the fragments. Veit has termed the latter syncytiolysin. Various experiments have been made in support of the view that the chorion produces a toxin which may cause various morbid changes during pregnancy unless continually destroyed by the maternal organism. Thus Politi injected sterile filtered extract of human placenta into rabbits, producing death in some cases with spasms and marked prostration. He states that the toxicity of the extract was lowest when the placentas of healthy women were used and most marked in the case of eclamptics. Ascoli has also made interesting experiments, in which placental infections produced some of the phenomena of eclampsia. Beside the influence of the blood in counteracting the syncytiotoxin, it is believed by some that the decidual cells also share in this function. Bandler holds, in addition, that the ovary also furnishes an element in its secretion which is antagonistic.

Functions of the Placenta

It has been clearly established that the placenta is entirely an organ of the chorion, consisting of projections of the latter termed villi, which are attached to the uterine mucosa, and bathed by maternal blood circulating among them.

Comparatively little is known as to the nature of the interchange of materials between the fetal and maternal

circulations through the medium of the villi. For many years the placenta has been regarded merely as the medium through which nutritive material and oxygen passed from the mother to the fetus, and the effete products of fetal metabolism from fetus to mother; it was considered to be a kind of fine sieve, through which percolation took place, or a diffusion membrane that favored osmosis. It is now almost certain that the transmission of substances between the maternal and fetal blood is not merely a matter of physics. The chorionic epithelium is believed by many to be a highly differentiated tissue, capable of carrying on complex vital processes, possessing powers of selection, elaboration, and even digestion. Marchand has suggested that the syncytium is the chief factor in the absorption of nutritive material from the maternal blood, the Langhans layer being more concerned with the transmission of waste products from ovum to maternal blood. Cavazzani and Levi state that there is no correspondence between the quantity of urea in the maternal and fetal blood, that there is more glucose in the former than in the latter, and that the density of the fetal blood is greater than that of the maternal blood. It appears that there are considerable variations in the transmission of substances through the placenta at different periods of pregnancy. Thus, in the last three months, there is a great increase in the iron potash, and lime stored up in the fetus. In the early months there is a great predominance of soda over potash.

Various materials may be stored in the placenta. Thus, it undoubtedly fixes glycogen. It is thought that albuminoid material is transmitted as soluble peptones, though this is not definitely known. There has been some question as to the possibility of the passage of maternal leukocytes through the walls of the villi entering the fetal circulation. Varaldo states that there are more leukocytes

in the umbilical vein than in the umbilical arteries, there being, on the average, considerably more per cm. in the former than in the latter, and that more of them contain iodophilic granules in the former than in the latter. It has, therefore, been concluded by several that leukocytes normally carry substances (possibly nutriment) to the fetal tissues. This has not been proved, however. In maternal leukocythemia there is no corresponding increase in white corpuscles in the fetal blood.

The placenta acts as a protective barrier against the invasion of the fetus by various poisons. It is more efficacious against some than against others. Porak's experiments on the guinea-pig, for example, show that in this animal copper passes easily, arsenic with difficulty, and mercury, not at all, the poisons being stored to a greater or less extent in the placental tissue. With regard to microörganisms and their toxins, little is known. Many microbes are able to pass from mother to fetus, but nothing is known as to the conditions associated with the transit. It does not appear that any placental lesion is necessary. The placenta appears to be more resistant to some organisms than to others. Thus it is clearly established that tubercle bacilli rarely pass through it; indeed, cases of Lehmann and others prove that though tuberculosis may begin in the placental tissue, the fetus may not be affected. In this connection, however, it must be noted that sometimes tubercle bacilli may be present in the fetus, though no lesions be present, since inoculations of guinea-pigs with portions of the fetal tissues may cause tuberculosis.

It seems certain that in the great majority of cases the placenta is the sole route by which microörganisms and toxins reach the fetus. It is possible that they may pass through the amnion into the amniotic fluid and thence enter the fetus, but this is probably a very rare mode of

injection. Charrin and Duclert's experiments on guinea-pigs suggest that the passage of germs through the placenta is helped or retarded by varying conditions of the maternal blood. Thus they found retardation when the maternal system was saturated with corrosive sublimate. When tuberculin, alcohol, lead acetate, or lactic acid were present, the passage of the germs seemed to be facilitated. Neelow has experimented on pregnant rabbits, and states that nonpathogenic organisms cannot pass from mother to fetus.

The placenta suffices to allow the fetus to grow and thrive in many diseased conditions of malformations incompatible with health or life in the adult. Pathologic conditions affecting the structure and function of the placenta endanger the life of the fetus. In many maternal diseases, doubtless, the fetus is destroyed as the result of changes in the placenta, affecting its structure or function, produced by its resistance to the toxic material in circulation.

The placenta also acts as the great excretory organ for the fetus. Savory long ago produced tetanus in a pregnant cat by injecting strychnine into the fetus in utero. The passage of other drugs has been similarly demonstrated by others. Charrin holds that toxins placed in the fetus, either directly or by the spermatozoa of the father, may pass to the mother. This might explain certain cases of immunization in syphilis (Colles' law). By injecting diphtheria toxin into the fetus in utero he has killed the mother animal. Guinard and Hochwelker have shown experimentally that the passage of drugs from the fetus to the mother is stopped if the former is killed, and that if the fetus be injected after its death the drug is only found in its tissues. Baron and Castaigne have found that drugs introduced into the amniotic fluid are also transmitted to

the maternal tissues, though much less rapidly than when injected into the fetus. If the latter be dead, the substances do not pass to the maternal circulation.

I have already referred to the theory that the chorionic epithelium produces an internal secretion, which may exercise a deleterious influence on the maternal system. Some hold that it may also act as a destroyer of certain elements circulating in the maternal blood which might be toxic to the fetus if it should enter the circulation of the latter.

THE HISTORICAL RELATIONS OF MEDICINE AND SURGERY

BY THOMAS CLIFFORD ALLBUTT

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IT was, I think, in the year 1864, when I was a novice on the honorary staff of the Leeds General Infirmary, that the unsurgical division of us was summoned in great solemnity to discuss a method of administration of drugs by means of a needle. This method having obtained some vogue it behooved those who practiced "pure" medicine to decide whether this operation were consistent with the traditions of purity. For my part, I answered that the method had come up early, if not originally in St. George's Hospital, and in the hands of a house physician, Dr. C. Hunter; that I had accustomed myself already to the practice, and proposed to continue it; moreover, that I had recently come from the classes of Professor Trousseau, who, when his cases demanded such treatment, did not hesitate himself to perform paracentesis of the pleura, or even incision of this sac or of the pericardium. As for lack, not of will, but of skill and nerve, I did not intend myself to perform even minor operations, my heresy, as one traitorous in thought only, was indulgently ignored; and we were set free

to manipulate the drug needle, if we felt disposed to this humble service. About this time certain Fellows of the London College of Physicians, concerned with the diseases of women, had been making little operations about the uterus, and meeting with but slight rebuke, they rode on the tide of science and circumstance, encroaching farther and farther, until they were discovered in the act of laparotomy; and rather in defiance than by conversion of the prevailing sentiment within those walls, they went on doing it.

Meanwhile the surgeons, emboldened by great events in their mystery, wrought much evil to the "pure" physicians; accusing them with asperity of dawdling with cases of ileus and the like until the opportunity of efficient treatment had passed away; nay, audacious murmurs were heard that such "abdominal cases" should be admitted into surgical wards from the first. Then, by dexterous cures, growing bolder and bolder, the surgeons went so far as to make a like demand for cases of tuberculous peritonitis, of empyema, and even of cerebral tumor. As thus the surgeons laid hands on organ after organ which hitherto had been sacred to "pure" medicine, and as indeed the achievements of surgery became more and more glorious, not only the man in the street but the man of the Hospital Committee also began to tattle about the progress of surgery and the diminution of medicine, until it was only by the natural sweetness of our tempers that the surgeon and the inner mediciner kept friends. At a dinner given on June 30 last to Mr. Chamberlain, in recognition of his great services to tropical medicine, this vigorous statesman said, "I have often heard that while surgery has made gigantic progress during the last generation, medical science has not advanced in equal proportion;" then, while modestly disclaiming the knowledge to "distinguish between the respective claims of these two great professions," he generously testified that "medical re-

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Photogravure from a Photograph.

search assisted by surgical science has thrown a flood of light on the origin of disease, and that this at any rate is the first step to the cure of disease." Now Mr. Chamberlain is the first of English statesmen to ally himself actively with our profession; the first with imagination enough to apprehend the great part which medical science is playing in the world already, and to realize that only by medicine can vast surfaces of the earth be made habitable by white men, and those "great assets of civilization," the officers of our colonies, be saved alive. It seems to me, then, that the present is a critical moment in the relations of medicine and surgery, especially in England, where the two branches of the art have been separated so radically as to appear to be "two professions;" a moment when it is our duty to contemplate the unity of medicine, to forecast its development as a connected whole, and to conceive a rational ideal of its means and ends. But this large and prophetic vision of medicine we cannot attain without a thoughtful study of its past.

If, as from a height, we contemplate the story of the world, not its pageants, for in their splendor our eyes are dim, but the gathering, propagation, and ordination of its forces, whence they sprang, and how they blend this way and that to build the ideas and institutions of men, we may wonder at their creative activity, or weep over the errors and the failures, the spoliation and the decay, which have marred or thwarted them; and if we contemplate not the whole but some part of men's sowing and men's harvest, such a part as medicine, the keener is our sorrow and disappointment, or our joy and our hope, as we admire the great ends we have gained or dwell upon the loss and suffering which have darkened the way. "In the development of medicine," said Helmholtz, "there lies a great lesson on the true principles of scientific progress."

Pray do not fear, however, that to fulfill the meaning of the title of this address, I shall describe to you the history of medicine and the history of surgery, and on this double line compare and combine my researches; in the time allotted to me no such survey is possible. In the seventeenth century the handicrafts of anatomy, chemistry, and physiology so penetrated medicine that the separate influence of surgery is less easily discernible. My purpose, therefore, is to pass in review certain eminent features of the history of these departments of knowledge up to the end of the sixteenth century, and to compare them with a view to edification; your fear will be rather that I may tell my story with the unrighteousness of a man with a moral.

In his address on "Morgagni," at Rome, in 1894, Virchow said that medicine is remarkable in its unbroken development for twenty-five centuries; as we may say, without irreverence, from Hippocrates to Virchow himself. The great pathologist's opinion, however, seems to need severe qualification; if it be so, the stream has more than once flowed long underground. The discontinuity of medicine from Egypt to Crotona and Ionia is scarcely greater than from Galen to Avicenna; during which period, in spite of a few eminent teachers in the Byzantine Empire, it sank, in the West at any rate, into a sterile and superstitious routine.

Classical medicine, the medicine of the fifth century, B. C., is represented for us by the great monument of the Scriptures collected under the name of the foremost teacher of the age, Hippocrates; in genius perhaps the greatest physician of all past time. The treatises of the Canon may be divided into medicine, surgery, and obstetrics. The medical treatises, when read in an historical spirit, command our reverent admiration. Written at a time when an inductive physiology was out of reach, we are impressed nevertheless by their broad, rational, and almost scientific spirit, Medi-

cine, even when not dominated by contemporary philosophy, has always taken its color from it; and the working physiology of Hippocrates was that humoral doctrine, originally derived from Egypt and the East, which, as enlarged by Galen, ruled over medicine till recent times. Hippocrates, while distinguishing between the methods of outward and inward maladies (φανερὰ καὶ ἄδηλα νοσήματα), taught that even for the inner, by careful sight and touch, laborious inspection of excretions, and so forth, many facts are accessible to methodical investigations; yet, as in inner diseases the field for inference is more spacious, the data even of direct observation fell the more readily into the scheme of the four humors, and by this doctrine were so colored that, although observed with a rare clinical insight, they were set in the frame of a fictitious pathology.

How was it then that the speculative side of the medicine of Hippocrates embarrassed him so little? Because the clinical method of the school was soundly based upon the outward maladies, where direct induction was practicable. No sooner indeed does an inward affection—an empyema for example—work outwards than the mastery of Hippocrates becomes manifest. What we separate as surgery, surgery which, from Guy to Paré, by clerks, faculties, and humanists was despised as vile, and from Paré to Hunter as illiberal, was in the age of Hippocrates, as in all critical epochs of medicine since that age, its savior.

If then our admiration of the inner medicine of Hippocrates, great as it is, is a relative admiration, an admiration of the historical sense, of his outer medicine our admiration is instant and unqualified. Little as the fifth century knew of inward anatomy, as compared with Alexandria about two centuries later, yet the marvelous eye and touch of the Greek physician had made an anatomy of palpable parts—a clinical anatomy—sufficient to establish a medicine of

these parts of the body of which our own generation would not be ashamed.

In respect of fractures and luxations of the forearm, M. Pétrequin pronounces Hippocrates more complete than Boyer; in respect of congenital luxations richer than Dupuytren. Malgaigne again admires his comparison of the effects of unreduced luxations on the bones, muscles, and functions of the limb in adults, in young children, and before birth, as a wonderful piece of clinics. In Littré's judgment, the work of Hippocrates on the joints is a work for all time, On wounds Littré pronounces that the Hippocratic books must be pondered with deep attention; for they are founded on a wide experience, minute and profound observation, and an enlightened and infinitely cautious judgment. Permit me to call your attention, however, to certain of his counsels: That a wound be let bleed, in order to prevent inflammatory consequences; that if in fresh wounds healing by first intention may take place, suppuration or coction is the usual, and in less recent and in contused wounds the normal course; also that wounds should be treated with linseed and other poultices: counsels which, as we shall see presently, were to be as hotly contested in the thirteenth and fourteenth centuries as in the nineteenth. From amputation of the larger limbs he flinched, as did most if not all responsible surgeons down to Paré; for inner anatomy was ill-known, and ligature, even in wounds, made slow way, indeed, before Celsus, seems to have been unknown. Caries was not definitely distinguished from necrosis, but a case of disease of the palate with fallen nose irresistibly suggests syphilis. Of eye diseases we find much of interest; of obstetrical practice I must be content to say that it had reached a high standard; and to state once for all that when surgery flourishes obstetrics flourish.

It is by comparison of one part of the Hippocratic Canon

with another that we learn how a strong grasp of inner medicine was attained by way of intense devotion to its inductive or surgical side. And this not by a mere empiricism; for it may have been from Hippocrates that Aristotle learned how by empiricism (ἐμπειρία) we perceive a certain remedy to be good for this person or for that—for Socrates, let us say, or for Callias—when he has a certain fever; but that by reason we discern the characteristic common to all these particular persons, wherein they react alike. In his *Book of Precepts* Hippocrates tells us that τριβὴ μετὰ λόγου is the basis of all medical knowledge. Now τριβή is primarily a grinding or rubbing; so the student must rub and grind at nature, using his reason at the same time; but his reason must be a perceptive and interpretative not a productive faculty, for he who lends himself to plausible ratiocination (λογισμῷ πιθανῷ προσέχων) will find himself ere long in a blind alley; and those who have pursued this course have done no enduring service to medicine. How soundly, for the time, this lesson was learned we see in the theoretical appreciation of these several faculties in the first chapter of Aristotle's *Metaphysics* and in the Sixth Book of the *Ethics,* where the senses, it is urged, cannot really be separated from the mind, for the senses and the mind contribute each an element to every knowledge. I am disposed to suggest that this method of observation, experience, and judgment was established first in medicine, because medicine is both practical and imperative; and, as Aristotle points out, concerned with the individual patient; to our art, then, may belong the honor of the application of positive methods to other sciences.

The chief lesson of the Hippocratic period for us is that, in practice as in honor, medicine and surgery were then one; the Greek physician had no more scruple in using his hands in the service of his brains than had Pheidias or Archi-

medes; and it was by this coöperation in the fifth century that the advance was achieved which in our eyes is marvelous. As we pursue the history of medicine in later times we shall see the error, the blindness, and the vanity of physicians who neglected and despised a noble handicraft. The clear eyes of the ancient Greeks perceived that an art is not liberal or illiberal by its manipulations, but by its ends. As, because of its ends, the cleansing and solace of the lepers by St. Francis and Father Damien was a service of angels, so Hippocrates saw no baseness even in manipulations, which obtained for his followers the name of *coprophagi;* where there is no overcoming there is no victory.

Between Hippocrates and Galen, an interval of some five centuries, flourished the great anatomical and medical schools of Alexandria. Our only important source, however, for the medicine of the Alexandrian period is Celsus, who lived in the reign of Augustus. In Celsus we find that the surgical and obstetrical sides of it had made farther and substantial progress. Celsus, perhaps not himself a practitioner, is sometimes vague in detail; still, beyond the Hippocratic surgery, we read of treatment in piles, fistula, rodent ulcer, eczema, fractures, and luxations; the nasal passages were cauterized for ozena; dropsies were systematically tapped; hernias were submitted to radical cure; plastic operations were undertaken, and the larger limbs were deliberately amputated, though only in extreme need, and often with fatal results by secondary hemorrhage and otherwise.

How active surgery was from Celsus to Galen, and how honorable and progressive a part of medicine, we know from the scanty records of Archigenes of Apamea, who also practiced in Rome, in the reign of Trajan. Galen calls him an acute but too subtle a physician; such of his subtleties, however, as are known to us—his distinction between prim-

ary and consequential symptoms for instance—are to his credit. He applied the ligature in amputations, and Antyllus applied the method to the cure of aneurism, which indeed Rufus seems to have done before him. Galen tells us where he got his "Celtic linen thread" for the purpose, namely, "at a shop in the Via Sacra between the Temple of Rome and the Forum." We learn also, from Oribasius, that Antyllus practiced extensive resections of bone in the limbs, and even in the upper and lower jaw.

Galen came to Rome under Marcus Aurelius. In the biological sciences this great physician stands to Harvey, as in physics Archimedes stood to Galileo and to that other great physician, William Gilbert; Galen was the first, as for many centuries he was the last, to apply the experimental method to physiology. He embraced the ancillary sciences, he opened out new routes, and he improved the old. Unhappily, his soaring genius took delight also in speculation; and it was not the breadth of his science, nor the depth of his methodical experiment, but the height of his visionary conceits which imposed upon the Middle Ages. Galen did not himself forget the precept of Hippocrates: To look, to touch, to hear (καὶ ἰδεῖν, καὶ θιγεῖν, καὶ ἀκοῦσαι); but he did not wholly subdue himself to the πεῖρα τριβικὴ—this toilsome conversation with troublesome facts. Galen did not make any great mark on surgery; his tracts on the eye are lost; but, so far as we know, his surgery was adopted in the main from the Alexandrians and from Soranus. However, Galen successfully resected the sternum for caries, exposing the heart; and he excised a splintered shoulder-blade: moreover, with all his bent to speculative reason, we have no hint that he fell into the medieval abyss of regarding surgery as unfit for a scholar and gentleman.

After Soranus and Galen medicine came to the evening of its second day, to the long night before the rise of the

Arabian, Italian, and French surgeons of the twelfth, thirteenth, and fourteenth centuries.

In spite of the docile industry of Greek physicians of the Byzantine period, medicine gradually sank not into sterility only, but into degradation. The wholesome discipline of practical surgery had fallen off. Eastern folk, who bear heaven-sent sores with fatal stoicism, shrank from the profane hand of man; and the tradition of Galen made for a plague of drugs which were least mischievous when merely superfluous. Rhazes, Albucasis, Avicenna the Arabian Galen, had entered by the door of the East into a great scientific inheritance, and, if they did little to develop surgery, it still was with them a grave and an honorable calling; with them medicine had not yet lost her right arm. The small benefits of the Church to medicine issued in a far greater treachery. The Greek of Ireland, and of England in the time of Bede, was banished by Augustine and the Benedictine missionaries; and the medicine of Monte Cassino, itself a farrago of receipts, in the monkish hostels of the West fell lower and lower. We have reason, however, to believe that even in the cloister some fair surgery was making way, when it was finally abandoned to the "secular arm" by the Council of Tours, in A. D. 1163; and books on surgery and midwifery began to disappear from the clerical libraries. The University of Paris excluded all those who worked with their hands; so that its students of medicine had to abjure manual occupation, and to content themselves with syllogisms and inspections of urine, often, indeed, without any inspection of the patient himself. From the University the Faculty of Medicine took its tone, and the Surgical Corporation of St. Come aped the Faculty. But by the expulsion of surgery from the liberal arts, and the societies of learned men, medicine herself was eviscerated; thus was made the pernicious bisection of medicine which has not yet

spent its evil; the inductive foundations of the art were removed, and the clergy and the faculties, in France and England at any rate, devoted all their zeal to shoring-up the superstructure. Surgery saw its revenge, its bitter revenge; but in the ruin of its temple. In the thirteenth and fourteenth centuries surgery, hated and avoided by medical faculties, scorned in clerical and feudal circles, began in the hands of lowly and unlettered men to grow from a vigorous root; while inward medicine, withdrawing itself more and more from the laboratory of nature, hardened into the shell which till the seventeenth century was but a counterfeit. The surgeons of the thirteenth, fourteenth, and fifteenth centuries, reared in humble apprenticeships, not illiterate only, but forbidden the very means of learning, lay under heavy disadvantages; yet, such is the virtue of practical experience, inductive method, and technical resource, that by them the reform of medicine was made. Towards the end of the fifteenth century, indeed, this progress had slackened, soon to be reinforced, however, by new and urgent problems, not of the schools, but of direct rough and tumble with nature. Of these new problems, of which Paré became the chief interpreter, new epidemics and the wounds of firearms were the chief.

In medicine from the twelfth to the eighteenth centuries Italy led the world; in the schools of Salerno, Naples, Bologna, Padua, was contained a strong lay and imperial tradition which gave pause to clerical ascendency. Bologna, until the predominance of her law school, was indeed a large and plenteous mother to medicine in its full orb; but already in Salerno far-seeing men had begun to dread the divorce of surgery from inner medicine. The important Salernitan treatise of the end of the twelfth century, *The Glosses of the Four Masters on the Surgery of Roger and Roland,* edited by Daremberg and de Renzi, begins with a lament on the

decadence of surgery, which they attribute to two causes; namely, the division of surgery from medicine, and the neglect of anatomy. By the wisdom of Bologna and Naples, where chairs of surgery were founded, this ill-starred divorce was postponed; in his University of Naples indeed Frederick the Second made it a condition that surgery should be an essential part of medicine, should occupy as long a course of study, and should be established on anatomy "without which no operator can be successful."

Roger's *Practica Chirurgiae* was written in 1180, and though of course it rests upon the traditional surgery of his day, there are not a few points of interest in the book, such as certain descriptions suggestive of syphilis. For hemorrhage Roger used styptics, the suture, or the ligature; the ligature he learned no doubt from Paul of Egina; but Roger like most or all qualified physicians of the period, was a "wound-surgeon" only, that is, he did not undertake the graver operations. He was in favor, as a rule, of immediate extraction of weapons from their wounds; but in these wounds, even after extraction, he encouraged suppuration by stimulating applications within and around them, and dressed them with ointments on lint. To these points, especially to the promotion of pus, and the unctuous dressings, permit me again to draw your attention; for we enter now upon a surgical controversy which, pale reflection as it may be of the great surgical dayspring of the nineteenth century, is, historically speaking, of singular interest.

Hugh, of Lucca, says Malgaigne, is the first of the surgeons of modern Europe whom we can cite with honor. This tribute is a little strained; we may say, however, that of these honorable ancestors Hugh seems to have been a chief. I say "seems to have been;" for Hugh is even a dimmer giant than Roger of Roland. We know that he was born of honorable family about the middle of the

twelfth century; that he served as surgeon in the campaigns, and was present at the siege of Damietta; but of writing he left not a line. Such vision as we have of him we owe to his loyal disciple, probably his son, the Dominican Theodoric, Bishop of Cervia, and master of Henry of Mondeville. He completed his "surgery" in 1266, but his life was almost coterminous with the thirteenth century. What was Theodoric's message? He wrote thus: "For it is not necessary, as Roger and Roland have written, as many of their disciples teach, and as all modern surgeons profess, that pus should be generated in wounds. No error can be greater than this. Such a practice is indeed to hinder nature, to prolong the disease, and to prevent the conglutination and consolidation of the wound." In principle what more did Lister say than this? Henry of Mondeville made a hard fight for the new principle, but the champions of Galenism and suppuration won all along the line; and for five following centuries poultices and grease were still to be applied to fresh wounds, and tents, plastered with irritants to promote suppuration, were still to be thrust into the recesses of them, even when there was no foreign body to be discharged. If after all this, erysipelas set in—well, says Henry, lay it at the door of St. Eligius! Hugh and Theodoric for the fresh wound rejected oil as too slippery for union, and poultices as too moist; they washed the wound with wine, scrupulously removing every foreign particle; then they brought the edges together, forbidding wine or anything else to remain within. Dry and adhesive surfaces were their desire. Nature, they said, produces the means of union in a viscous exudation, or natural balm as it was afterwards called by Paracelsus, Paré, and Würtz. In older wounds they did their best to obtain union by cleansing, desiccation, and refreshing of the edges. Upon the outer surface they laid only lint steeped in wine. Powders

they regarded as too desiccating, for powder shuts in decompositing matters; wine, after washing, purifying, and drying the raw surfaces, evaporates. The quick, shrewd, and rational observations, and the independent spirit of Theodoric, I would gladly illustrate farther did time permit; in passing, I may say that he was the first to notice salivation as the result of administration of mercury in "skin diseases."

Both for his own merits, and as the master of Lanfranc, William Salicet was eminent among the great Italian physicians of the latter half of the thirteenth century. Distinguished in surgery, both as practitioner and author, he was also one of the protestants of the period against the division of the craft from inner medicine; a division which he justly regarded as a withdrawal of medicine from intimacy with nature. Like Lanfranc and all the great surgeons of the Italian tradition, and unlike Franco and Paré, he had the advantage of the liberal university education of Italy; but, like Paré and Würtz, he had also large practical experience in camp, hospital, and prison. His *Surgery* contains many case-histories. He discovered that dropsy may be due to a "durities renum;" he substituted the knife for the abuse of the cautery by the followers of the Arabs; he pursued the investigation of the causes of the failure of healing by first intention; he described the danger of wounds of the neck; he forwarded the diagnosis of suppurative disease of the hip, and he referred chancre and gangrene to "coitus cum meretrice."

The *Chirurgia Magna* of Lanfranc of Milan and Paris, published in 1295-96, was a great work, written by a reverent but independent follower of Salicet. He distinguished between venous and arterial hemorrhage, and generally used styptics; white of egg, aloes, and rabbit's fur was a popular styptic in elder surgery, though in severe cases ligature was

used. Learned man as he was, Lanfranc saw the more clearly the danger of separating surgery from medicine. "Good God!" he exclaims, "why this abandoning of operations by physicians to lay persons, disdaining surgery, as I perceive, because they do not know how to operate . . . an abuse which has reached such a point that the vulgar begin to think the same man cannot know medicine and surgery. . . . I say, however, that no man can be a good physician who has no knowledge of operative surgery; a knowledge of both branches is essential" (*Chirurgia Magna*).

Henry of Mondeville, of whom we hear first in 1301, as surgeon to Philip the Fair, was for the most part a loyal disciple of Lanfranc, and, aided as it would seem by Jean Pitard, also surgeon to the King, attempted for wounds to introduce the new methods of Hugh and Theodoric; for his pains he exposed himself to bad language, threats, and perils; and "had it not been for Truth and Charles of Valois," to far worse things. So he warns the young and poor surgeon not to plow the sand; but to prefer complaisance to truth, and ease to new ideas. I may summarize, briefly, the teaching of Henry on the cardinal features of the new method: Wash the wound scrupulously from all foreign matter; use no probes, no tents—except under special circumstances; no oily nor irritant applications; avoid the formation of pus, which is not a stage of healing, but a complication; do not, as Galen teaches, allow the wound to bleed with the notion of preventing inflammation, for you will only weaken the patient's vitality (*virtus*), give him two diseases instead of one, and foster secondary hemorrhage; distinguish between oozing hemorrhage, hemorrhage by jets, and that which pumps out of an inward wound, using for the first, styptics, and for the last two the cautery, or where practicable, digital compression for not less than a

full hour; when your dressings have been carefully made, do not interfere with them for some days; keep the air out, for a wound left in contact with the air suppurates; however, should pain and heat arise, open and wash out again, or even a poultice may be necessary, but do not pull your dressings about—nature works better alone; if first intention fail, she may succeed in the second, as a jeweler, if he can solder gold to gold does so, if not, he has to take to borax; these resources, however, we learn well, not by arguing but by operating. By the new method you will have no stinks, shorter convalescence, and clean, thin scars. In wounds of the neck he says that alterations of the voice suggest implications of the larynx. When using the word "nature," he freely admits that the word is an equivocal one, but he would speak of her allegorically as a lute-player to whose melodies the physician has to dance. Again he says: "Every simple wound will heal without any notable quantity of pus, if treated on Theodoric's and my instructions. Avoid every cause of formation of pus, such as irritating applications, exposure to air, high diet, edema, local plethora. Many more surgeons know how to cause suppuration than how to heal a wound." Now let me remind you that, until Hugh of Lucca, the universal doctrine was that suppuration or coction is necessary; and that if it does not set in, it must be provoked.

The greatest of the French surgeons before Paré was Guy of Chauliac, who flourished in the second half of the fourteenth century. He studied in letters and medicine at Toulouse and Montpellier; in anatomy at Bologna. The surgeon, ignorant of anatomy, he says, "carves the human body as a blind man carves wood." The Arabs and Paris said: Why dissect if you trust Galen? but the Italian physicians insisted on verification. Guy was called to Avignon by Clement VI. During the plague of 1348 he

stayed to minister to the victims, and did not himself escape an attack, in which he was ill for six weeks. His description of this epidemic is terrible in its naked simplicity. He gave succor also in the visitation of 1360.

His *Chirurgia Magna* I have studied carefully, and do not wonder that Fallopius compared the author to Hippocrates, and that John Freind calls him the prince of surgeons. The work is rich, aphoristic, orderly, and precise. Guy was a more adventurous surgeon than Lanfranc, as was Franco, a later Provençal, than Paré. He did not cut for stone, but he operated for radical cure of hernia and for cataract; operations till his time left wholly to the wayfaring specialists. In Guy the critical spirit was awake. He scorns the physicians of his day, "who followed each other like cranes, whether for fear or love he would not say." In respect of principles, however, Guy was not infallible. Too sedulous a disciple of Galen, he was as a deaf adder to the new message of Hugh, Theodoric, and Henry; and not only was he deaf himself, but, as the authoritative master of the early renascence, he closed the ears of his brethren and successors, even to the day of Lister.

This vigorous life which surgery gave to the medicine of the thirteenth and fourteenth centuries was stifled in the West by the pride and bigotry which, culminating in the Council of Tours, had thrust surgery down into the ranks of illiterate barbers, reckless specialists, and adventurous charlatans. In Italy, however, the genius and bent of the people for art as well as for philosophy, and the ascendency of the secular element in the universities, still kept surgery in its place as "the scientific arm of medicine."[1] Thus in Italy of the fifteenth century surgery did not droop as it did in the West; if it slumbered for a spell, it soon awoke again, refreshed in the new Hellenism. Pietro di Argelata

[1] A phrase which Sir John Burden Sanderson once used in my hearing.

(d. 1423), Doctor of Arts and Medicine, and professor of Bologna, wrote an excellent *Surgery* full of personal observation; and perhaps for the first time, was frank about his own mistakes. Bertipaglia, another great Paduan professor, flourished a little after Argelata, but was a man of less originality. Argelata followed the lead of Henry and Guy in some bolder adventure in operative work as distinguished from mere wound-surgery, and was himself a learned and skillful practitioner.

In the midst of the mainly Arabist professors of medicine of the fifteenth century arose Benivieni, the forerunner of Morgagni, and one of the greatest physicians of the late Middle Ages. This distinguished man, who was born in 1448 and died in 1502, was not a professor but a Doctor of Medicine, a man of culture and an eminent practitioner in Florence. Although born in the new platonism, he was, like Mondeville, one of those fresh and independent observers who surrender to no authority, to Arab nor Greek. Yet for us Benivieni's fame is far more than all this; for he was the founder of the craft of pathological anatomy. So far as I know, he was the first to make the custom, and to declare the need of necropsy to reveal what he called not exactly "the secret causes," but the hidden causes of diseases. Before Vasalius, Eustachius, or Fallopius were born, deliberately and clear-sightedly he opened the bodies of the dead as keenly as any pathologist in the more spacious times of Morgagni, Haller, or Senac, or of Hunter, Baillie, and Bright. Among his pathological reports are morbus coxae (two cases), biliary calculus (two cases), abscess of the mesentery, thrombosis of the mesenteric vessels, stenosis of the intestine, "polypus" of the heart, scirrhus of the pylorus, ruptured bowel (two cases). He gives a good description of senile gangrene. Thus necropsy was first brought into practice to supplement the autopsy which the surgeon had long practiced in the living subject.

It would be unjust to forget that in the latter half of the fifteenth century Paris admitted some reforms; celibacy for physicians was abolished, and with it diminished the allurements of prebends and rectories, and the pernicious practice of the "médecins reclus" who did not visit patients nor even see them, but received visits from ambassadors who brought gifts and vessels of urine, and carried back answers far more presumptuous than the well-known counsel of Falstaff's physician. Still not only was reform in Paris very grudging, but it was capriciously favored and thwarted by the French court. The faculty denied to St. Come "esoteric" teaching, diagnosis, and the use of medical therapeutics; a jealousy which ended in the physician being requested to do little more than write the prescription. Aristotle was quoted as unfavorable to the "vulgarizing of science." Joubert was attacked for editing Guy in the vernacular. Fortunately the surgeons were carried into the field of battle, a far better school than the Paris Faculty.

Thus it was that in the opening of that great century in the history of the human mind, the sixteenth century, we find Italian medicine still in the van, until the birth of the great French surgeons, Franco and Paré, and of Gersdorff and Würtz in Germany.

Franco, like Paré, was no clerk; he came of a class lower even than that of Paré and the barbers, the wayfaring class of bonesetters, oculists, plastic operators, and cutters for stone and hernia; "runagates," as Gale calls them. Thus dangerous visceral operations, and those on the eye, which but too often were swiftly disastrous, fell into the hands of wandering and irresponsible craftsmen, men of low origin, and too often ignorant, reckless, and rapacious. As the truss was a very clumsy instrument, at any rate till the end of the seventeenth century, the radical cure of hernia was in great demand. It is not the least of the merits of

Franco that he brought these operations within the lines of responsible surgery, and thrust them into the ken of Paré and Fabricius. This illustrious Provençal surgeon—*"ce beau génie chirurgical,"* as Malgaigne calls him, in declining the task of entering upon so full a life—was born about 1503. He began as an apprentice to an operating barber and hernia specialist. He had no more "education" than Paré or Würtz, and he was spared the misfortune of a speculative intellect. He picked up some anatomy, educated himself by observation, experience, and manipulation, and as a single operator or "Master," won considerable renown. As upright and modest as Paré, though he never attained Paré's high social position, he submitted to call in the physician, and took his quiet revenge in the remark that the physicians did not know enough to distinguish good surgery from bad. Nicaise says roundly, "No surgeon made such discoveries as Franco; for hernia, stone, and cataract he did much more than Paré." Whether from incapacity or the brutality of habit, during the Middle Ages and down even to the middle of the seventeenth century, it had been the custom in operating for hernia to sacrifice one or even both testicles, an abuse against which Franco took successful precautions, for he proved that the canal could be closed and the ring sutured without castration. In irreducible inguinal hernia he distinguishes between opening and not opening the sac, and describes adhesions of sac and intestine. From him, indeed, dates the rational operation for strangulated hernia, and in strangulated scrotal hernia he founded the method. Paré, and after him Petit, condemned the ablation of the testicle, which procedure, however, many surgeons thought quite good enough for priests; and Paré gives credit to Franco for these advances, though Fabricius does not even mention them. On the interesting subject of plastic operations, which attained a remarkable

vogue in the Middle Ages, and were but restored by Tagliacozzi, I have not now time to speak.

The very eminence of Ambroise Paré encourages if it does not command me to be content with a few words of commemoration. Himself of humble origin, he won for surgery in France a social place and respect it had never attained before. Born in 1517, he became a barber's apprentice in the Hôtel Dieu, whence he followed the campaign of Francis I against Charles V. As he could not write a Latin treatise, his admission to St. Come was of course opposed by the Faculty; but Paré stoutly declared that the vernacular tongue was essential to the progress of medicine. Riolan the elder, who had taken part in the opposition, wrote a tract on the other side, in 1577, with the following insolent title: *Ad impudentiam quorundam Chirurgorum qui medicis aequari et chirurgiam publicè profitere volunt pro dignitate veteri medicine apologia philosophica.* Now at this time Paré was 60 years of age and surgeon to the King. If in comparison with Paré, Haeser treats Franco somewhat slightingly, and if in some respects Paré may not be lifted far above some of his great Italian contemporaries, such as Maggi, Carpi, or Botallo, yet taken all around the founder of modern surgery surely surpasses all the physicians of his time as an independent, original, and inventive genius, and as a gentle, masterly, and true man. Yet I am often surprised to see, even to-day, the invention of ligature of arteries attributed to Paré, whose surprise, if our journals have an astral shape, must be greater still, seeing that he himself refers the ligature to Galen. The attribution is of course a legend. Malgaigne discreetly claims no more for Paré than the application of the ligature from wound-surgery to amputations; but in my opinion even this claim goes beyond the truth of history. Celsus speaks of the ligature as an ordinary method

in wounds; from Oribasius we learn that Archigenes of Apamea even tied vessels in amputation, after fixing a tight band at the root of the limb. It seems probable that, unless performed with modern nicety, secondary hemorrhage must have been frequent; indeed in 1773, Petit deliberately discarded the ligature, as Franco and Fabricius had done before him. Military surgeons considered even Paré's "ligature en masse" too delicate a method for the battle-field. It is a more intelligent service to this great man to point out that the ligature and other operative details were no singular devices, but orderly steps in a large reform of method in amputation, a reform made imperative by the ravages of fire-arms, ravages which could not be covered up with Galenisms.

It is the privilege of the historian to make light of time and space; and it is not easy to leave Paré and his times without some reflection upon the great German surgeons, Brunschwig, Gersdorff, and Würtz, who, like him, were concerned with the effects of firearms. In Italy in the sixteenth century surgery was somewhat on the wane, but in Germany Würtz, in the freshness and originality of his mind and in his freedom from scholastic convention, reminds us of Paré.

Paracelsus (born 1491) was a surgeon and no inconsiderable one. Had this extraordinary man been endowed with a little patience he would have been a leader in wound-surgery, though, like Würtz, he was not an operator. He pointed out not only the abuse of the suture by the surgeons of the day, but also that suppuration is bad healing, for, if left to herself, nature heals wounds by a natural balm, a phrase which Paré adopted. In his *Grosse Wündarznei* he says he began at the surgical because it is the most certain part of medicine, and time after time he rebukes those who withdraw medicine from surgery. Brunschwig was

indeed the first surgeon to write upon the surgery of gunshot wounds with any fullness or precision. He held, however, as Vigo after him, that a gunshot wound was a poisoned wound; and, to eliminate the poison by free suppuration, used the medicated tents, or in case of thorough penetration, the setons which were to arouse the angry antagonism of Würtz.

Felix Würtz, like Franco and Paré, had also the good fortune to escape a scholastic education; he was lucky enough, however, to enjoy the liberal education of Gesner's friendship, and to listen to the fiery disputes of Paracelsus. Gifted with an independent and penetrating mind, he is as fresh and racy as Henry of Mondeville had genius enough to be in spite of the schools. Like all his compatriots, he wrote in the vernacular; and for its originality and conciseness, Würtz's *Practica,* published in 1563, stands in a very small company. Had he known as much anatomy as Paré, his defect in which he bewails, he might have been as great a man, for his clinical advances were both new and important. He protests against the kind of examinations for practice held in some cities where candidates patter off cut and dried phrases like parrots, while apprentices "play upon the old fiddle the old tune continually." By setting his face against cataplasms and grease, he made for progress, though neither he nor Paré attacked suppuration in principle as Theodoric and Henry had done. His chief title to fame, a fame far less ripe of course than that of Sydenham, but, as it seems to me, not unworthy to be remembered beside it, lies in his clinical acumen, and especially in his conception of wound infections and their results. His description of diphtheria is especially remarkable.

While surgeons from generation to generation were making the solid progress I have indicated, what were the

physicians about? Now, of the fantastic conceits they were spinning, of the gross and blundering receipts with which they stuffed their books, I have not time to speak; fortunately, history has but too well prepared you to dispense with this side of the story. One example I will give you: In the sixteenth century the air was rent by the clamor of physicians contending in two camps with such ardor and with such acrimony that the Pope, and even Charles the Fifth, interfered—and on what momentous principle? Whether, in such a disease as pleuro-pneumonia, venesection was to be practiced on the same side as the disease or on the opposite side? Brissot, who questioned the Galenical tradition in this matter, was declared by the Emperor to be a worse heretic than Luther. Unfortunately for Imperial medicine, if indifferently for science and the public weal, it came out, on the recovery of the text of Hippocrates, that Brissot had happened to be on the side of the father of medicine.

England, if by England we mean no more than the Isles of Britain, makes no great show in medieval or renascence surgery. Arderne was probably a far better surgeon than Gilbert or John of Gaddesden; but he is little more than a name. Nor does it do to peruse Thomas Gale (1507-1586?) after Mondeville, Guy, Paré, Würtz, or Maggi. In the *Wounds Made by Gonneshot,* the third part of his *Surgery,* lies Gale's merit, that he also withstood "the gross error of Jerome Brunswicke and John of Vigo, that they make the wound venomous."

With the sixteenth century my survey must end; from this time medicine entered upon a new life, upon a new surgery founded on a new anatomy and on a new physiology of the circulation of the blood and lymph. These sciences, thus renewed, not only served surgery directly, but by the pervading influence of the new accuracy of observation, and

the enlargement of the field of induction, also indirectly modified the traditional medicine of physicians unversed in methods of research, as we observe in the objective clinical medicine of Sydenham. Our physiologists tell us that destruction is easy, construction difficult; but in the history of medical dogma this truth finds little illustration. So impatient is the speculative intellect of the yoke of inductive research, so tenacious is it of its castles in the air, that no sooner did Harvey, by revealing the mechanics of the circulation, sap the doctrines of the schools, than some physicians instantly set to work to run up the scheme of iatro-physics; others to build a system of iatro-chemics, but upon Von Helmont rather than on Willis and Mayow; while Hoffman and his school resuscitated the *strictum* and *laxum* syllogisms of the Greek Methodists.

In this sketch of the past, a sketch necessarily indiscriminate, but not, I trust, indiscreet, we have seen that up to the time of Avicenna, medicine was one and undivided; that surgery was regarded truly, not as a department of disease, but as an alternative treatment of any disease which the physician could reach with his hands; that the cleavage of medicine, not by some natural and essential divisions, but by arbitrary paltering to false pride and conceit, let the blook run out of both its moieties; that certain diseases thus cut adrift, being nourished only on the wind, dried into mummy or wasted in an atrophy, and that such was medicine; while the diseases which were on the side of the roots, if they lost something of their upper sap, were fed from below, and that such was surgery.

Thus the physicians who were cut off from the life-giving earth, being filled with husks and dust, became themselves stark and fantastic. Broadly speaking, until the seventeenth century pathology was a factitious schedule, and medicine a farrago of receipts, most of them nauseous,

many of them filthy; most of them directly mischievous, all of them indirectly mischievous as tokens of a false conception of therapy. A few domestic simples, such as the laxatives, are indispensable; for the rest we are tempted to surmise that mankind might have been happier and better if Dioscorides had been strangled in his cradle.

This is the truth I have tried to get home to you, that in the truncation of medicine the physician lost not only chiefly a potent means of treatment; he lost thereby the inductive method; he lost touch with things; he deprived his brains of the coöperation of the subtlest machine in the world—the human hand, a machine which does far more than manufacture, which returns its benefits on the maker with usury, blessing both him that takes and him that gives.

Pure thought, for its own sake, especially in early life, when the temptation to it is strong and experience small, seems so disinterested, so aloof from temptation of gain, that in the history of ideas, speculation and the construction of speculative systems have played but too great a part, and have occupied but too many minds of eminent capacity. We must assume then that they have served—and for aught we know may still serve—some good end. It seems hardly likely that age after age men would busy themselves to build up these vast constructions in idle exercise. That nature is wasteful we know but too well; yet she is wasteful by the way, not in the main direction of her work. If some of her seed falls on stony ground, if her rain falls on the just and on the unjust, yet the sowing and the rain are in the main fruitful and delightful. Peradventure, in our modern conviction of the efficiency of the inductive method we may be too ready to denounce other methods which, hard as it may be for us to conceive, may yet play some lasting part in evolution. Even in our own day we may

become too analytical; on our good side we may be too exclusive. In the pale hue even of inductive analysis may we not get sick, lose resolution in too much deliberation, overlook the concrete, and forget that if by any mode of generalization we lose hold of individuals in types, and of things in the negations and eliminations of abstraction we may fall ourselves into the very error of the "school-authors." If the search for entities was false, may there not be a sort of imposition in "laws"? When in the last analysis we attain to unresolved residua may we not err in giving even to a true residuum too solid a name? Whether it be the summation of phenomena or a vision of the imagination an abstraction is an abstraction, and abstractions carry us a long way from deeds and things.

In the minds of academical teachers the notion still survives that the theoretical or university form and the practical or technical form of a profession or trade may not only be regarded separately, and taught in some distinction, which may be true, but in independence of each other; nay, that the intrusion of the technical quality by materializing, degrades the purity or liberality of the theoretical; that indeed if he had not to get his daily bread the high-minded student may do well to let the shop severely alone. Thus the university is prone to make of education thought without hands; the technical school, hands without thought; each fighting shy of the other. But if in a liberal training the sciences must be taught whereby the crafts are interpreted, economized, and developed, no less do the crafts, by finding ever new problems and tests for the sciences, inseminate and inform the sciences, as in our day physics are fertilized by the fine craft of such men as Helmholtz, Cornu, and Stokes; and biology by that of Virchow, Pasteur, and Lister. At the commemoration of Stokes in Westminster Abbey, Lord Kelvin honored in him the "com-

bination of technical skill with intuition;" and Lord Rayleigh admired in him "the reciprocity of accurate workmanship and instinctive genius;" appreciations no less true of these two distinguished speakers themselves. If it be true, as I have been told, that the University of Birmingham has a coal-mine upon the premises, I am ready to believe that the craft of coal-getting, by carrying practice into thought, will fortify the web of theory.

There exists, no doubt, the contrary danger of reducing education to the narrow ideas and stationary habits of the mere artisan. By stereotyped methods the shop-master who does not see beyond his nose, may cramp the 'prentice, and this 'prentice becomes shop-master in his turn. If in the feudal times, and times like them in this respect, manual craft was despised, and the whole reason of man was driven into the attenuated spray of abstract ingenuity, in other times or parts of society a heavy plod of manual habit so thickened "the nimble spirits in the arteries" that man was little better than a beaver: on the one side matter, gross and blockish; on the other, speculation vacuous of all touch of nature. We need, the elevation, the breadth, the imagination which universities create and foster; but in universities we need also bridges in every parish between the provinces of craft and thought. Our purpose must be to obtain the blend of craft and thought, which, on the one hand, delivers us from a creeping empiricism, on the other, from exorbitant ratiocinations. That for the progress and advantage of knowledge the polar activities of sense and thought should find a fair balance, is set forth judicially enough in modern philosophy, and is eminent in great examples of mankind. Moreover, it is apprehended in the reciprocal tensions of faith and works, of hypothesis and experience, of science and craft. In our controversies on theory and practice, on universities and

technical schools, on grammar and apprenticeship, we see their opposite stresses. The unison is far from being, as too often we suppose, one merely of wind and helm, it is one rather of wind and wing; it consists not in a mere obedience of hand to mind, but in some mutual implication, or generative conjugation of them. How these two forms of impulse should live in each other, we see in the Fine Arts —in the swift confederacy of hand and mind in Dürer, Michael Angelo, Rembrandt, Velasquez, Watteau, Reynolds. The infinite delicacy of educated senses is almost more incredible than the compass of imagination. When they unite in creation no shadow is too fleeting, no line too exquisite for their common engagement and mutual reinforcement. Michael Angelo and Leonardo da Vinci, the greatest craftsmen perhaps the world has seen, were as skillful to invent a water-engine, to anatomize a plant, or to make a stonecutter's saw, as to build the dome of St. Peter above the clouds of Christendom.

Solve the problem as hereafter we may, now we can take heed at least that energy shall not accumulate about one pole or the other. Our little children have a message to us if we would but hearken to them. Every moment they are translating action into thought and thought into action. Eye, ear, and hand are incessantly on the watch and in pursuit, gathering incessantly for the mind and the forms of thought which as rapidly issue again in new activities. If, as we mature, we gain the power of restraint, it is not that we shall cease to act, that the mind shall depose the hand, but that these variables shall issue in a richer and richer function. If we forget the hands, that cunning loom which wove our minds, if thrusting them into our pockets, we turn our eyes inwards, will our minds still truly grow? That by virtue of the apposable thumb monkey became man is no metaphor; in its measure it is sober truth. For

the last millennium too much thinking has been the bane of our profession; we have actually made it a point of honor to ignore the hands out of which we were fashioned, and in this false honor to forget that the end of life is action, and that only by action is action bred. While we profess to admire Bernard Palissy or Jean Goujon, the medieval mason or the medieval goldsmith, we act nevertheless as if fine arts only are honorable, and mechanical arts servile; whereby we blind ourselves to the common laws of growth, which, knowing not these distinctions, deal out barrenness to those who make them. We begin even with our children to wean them from the life of imaginative eyes and of thoughtful fingers; and instead of teaching them to rise from simple crafts to practical crafts, to scientific crafts, or to lovely crafts, and thus to pursue the mean of nature herself, we teach them the insolence that, except in sports, the mind should drop the acquaintance of the fingers.

Shall we wonder then that in this generation bold men call English people stupid; all stupid save those few men of genius or rich talent, who, like Gilbert, Harvey, or Darwin, were great enough to be true to eye and hand, and to breed great conceptions by their intimate coition with the mind? Shall we wonder then that medicine fell into sterility when by most unnatural bonds surgery, her scientific arm, was tied behind her, and her sight was turned inwards from processes to formulas? Shall we wonder that even in the eighteenth century, when medicine had begun tardily to occupy itself in the crafts of pathology and chemistry, one visionary after another, striding in long procession athwart the barren wilderness of physic, wasted his generation in squeamish evasion of the things that happen, and in vain pursuit of vacuous unities? Yet, if to the high stomachs of our forefathers surgical dabblings were common and unclean, still there remained some eyes curious enough and

some fingers dexterous enough to carry the art back to the skill of Hippocrates, and forward to the skill of Lister; but it was by the mouths of barbers and cutters, rather than of the pharisees of the colleges, that medicine breathed her lowly message to her children.

THE HISTORY AND DEVELOPMENT OF SURGERY DURING THE PAST CENTURY.

BY FREDERIC S. DENNIS.

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THE first word of the speaker on this occasion must be a personal one of respectful acknowledgment. To be invited by the administrative board to deliver an address upon any theme before this august Congress, composed as it is of many of the world's most distinguished men of science, is a distinction which any one might justly prize. But to be chosen as the orator upon a topic so important, far-reaching, and comprehensive as the history and development of surgery during the past century is an honor so exalted that while it pleasantly gratifies, it also most seriously appalls.

Permit me at the outset to record my profound and grateful appreciation of the high honor thus conferred, and at the same time to express the hesitation which I feel in attempting to handle so great a theme within the necessary limitations of the hour. It is obvious that the task is as fascinating as it is difficult. It is undertaken at the earnest solicitation of friends who have much stronger confidence than the speaker in his ability to narrate in a fitting way the triumphs of our great science.

To weigh the surgical events of a hundred years ago, and the motives which gave rise to them, requires us to summon to our thought, as far as possible all the circumstances of that period. Only when this retrospect is made, and the meager results then attained by surgery, are compared with its notable achievements in the present day, can the idea be fully grasped of how great, how wonderful, how grand, has been the progress during the past century. The advances which have been made in every department of human activity, the victories gained in every field, the innumerable inventions, the marvelous discoveries, the daring exploits carried forward to successful completion, the magnificent results secured along all scientific lines, are all discussed and celebrated in the meeting of this International Congress. But while the other sciences have indeed thrilling stories to relate, and can point with just pride to excellent deeds performed, the science of surgery stands out in bold relief and conspicuous grandeur, apart from and above the others, in that it deals directly with human life, that most precious of mortal possessions, often lending to it not only a helping but a saving hand. At the same time its story is so simple and yet so grand that the child and savant may alike participate in the pleasure which the wonderful narrative is fitted to convey.

Surgery as a science made no profound impression upon the world until about a century ago. But from that time to the present the almost miraculous works which it has wrought, increasingly marvelous with every passing year, have aroused astonishment and admiration in every quarter of the globe.

In order to appreciate what surgery has accomplished, it is necessary to refer briefly to its status prior to 1800. A little over a century ago surgery as a science had no existence. It had no definite or dignified position. It re-

ceived no aid or support from reigning monarchs or kings. It was in the hands of charlatans and quacks and barbers, and it was practiced with some few exceptions by uneducated and irresponsible men. It was only in 1800 that surgery was divorced from the traditions of the past and was given a place among the sciences. It was in 1800 that the Royal College of Surgeons obtained its charter from Parliament, which had refused over and over again to grant it. So bitter was the opposition to granting a charter to the "Company of Surgeons" that Lord Thurlow is said to have proclaimed in the House of Lords that "there is no more science in surgery than in butchering." It was only by an appeal to King George the Third that this charter was finally obtained. In marked contrast to this attitude of Parliament was the scene enacted at the Centenary of the College of Surgeons, a few years ago. Here were assembled the foremost statesmen of England, and the leading scientists of the world, to do honor to the occasion. The King himself joined in the banquet as an honorary member of the Guild. During all these centuries prior to 1800, as has already been stated, surgery had no established place among the sciences. Medicine, on the other hand, had a well-defined and honorable status. It received abundant help and liberal support from kings and rulers. Thus it becomes evident how bitter the struggle has been for surgery to establish its claim to honorable and dignified recognition. Thus it becomes apparent that the difficulties to be overcome to establish that recognition were then insurmountable. This is not to be wondered at when pain in surgical operations, inability to control hemorrhage, and prevention of blood-poisoning, were the obstacles to the successful practice of the art. These evils retarded the growth of surgery. Their removal since 1800, and chiefly during the past quarter of a century, has cleared

the way for the achievements of the present day. From Hippocrates, who was born 460 B. C., to 1800 A. D., surgery made little advance. It was practiced by illiterate men, with here and there a masterful mind groping in the dark for light. There were two great discoveries prior to 1800 that had an influence on the progress of surgery after that time, and without which surgery could never have become a recognized science. The first discovery refers to the circulation of the blood, which was made by Harvey in 1628, and the further discovery of the capillary system by Malpighi in 1661. The fearful dread of hemorrhage from an unknown source prevented any operations except those of dire necessity, which were generally performed through dead and gangrenous tissue. The second discovery refers to inflammation, the healing of wounds by blood-clot, and the ligation of the vessels in their continuity, by John Hunter, who was born in 1728. These two great discoveries prior to 1800, like the two great discoveries after 1800, viz., anesthesia and antiseptics, have enabled surgery to establish its just claim to recognition among the sciences. These four great discoveries, the circulation of the blood, the repair of wounds, anesthesia, and antiseptics, are the four corner-stones upon which a superstructure has been erected that has become a veritable temple of science, the dimensions of which eclipse in grandeur all other temples.

The progress has been greater during the past century than in all the preceding centuries since the beginning of the world. This progress which surgery has made is due, in great part, to the dissemination of medical literature, to the formation of medical libraries, to the organization of modern hospitals, to the equipment of scientific laboratories, to the foundation of medical schools, to the establishment of medical museums, to the organization of training-schools for nurses, and, finally, to the two transcendent discoveries

—anesthesia and antiseptics. That medical literature has had much to do with the advance of surgery during the past century is evident when it is shown that at the beginning of the Revolutionary War there was only one medical book, three reprints, and about 20 pamphlets by American authors, while to-day there is on the average one new book for each working day in the year, 300 journals, and 5000 original journal articles. American writers are publishing annually at least 500 medical volumes, to say nothing of the issuance of nearly 10,000 journal articles each year. In the department of surgery alone, during the two years of 1879-1880, there were written in America no less than 45 surgical books of importance and value, together with 1717 journal articles beside, and from this record of nearly a quarter of a century ago some idea can be gained of what surgical literature has accomplished at the present time.

That the foundation of medical libraries has had much to do with the progress of surgery becomes manifest when it is considered that a hundred years ago there were in this country only about 250 medical volumes, all told, while to-day there are nearly 160,000 volumes in the libraries of medical colleges alone, to say nothing of the large and general medical libraries throughout the country, without mentioning the thousands and thousands of volumes in the medical libraries in Europe.

That modern hospitals have had much to do with the advance of surgery is apparent when it is remembered that there were scarcely any hospitals a hundred years ago, while to-day they crowd nearly every city and town. This statement is emphasized by the fact that in New York and in Philadelphia there are four free beds to every 1000 of their respective populations; and by the further fact that any American city without adequate hospital accommodations is looked upon as in disgrace and behind the age;

and, further, that the 433 hospitals in this country which maintain training-schools for nurses exceed in value $73,-000,000, and their endowments exceed $18,000,000. These figures represent less than a fourth of hospital wealth, since many of the hospitals maintain no training-schools.

That the establishment of scientific laboratories has been a potent factor in surgical progress is proved by the fact that millions of dollars have been recently devoted to this purpose, and the work performed in these laboratories has had a tremendous influence upon the world. To Andrew Carnegie is due the credit of building the first purely scientific laboratory for medical and surgical research in this country; and from his example other like laboratories have been established in the land, until now America eclipses the world in the wealth and magnificence of its scientific institutions. The Laboratory of Hygiene in Philadelphia and the Caroline Brewer Croft Fund for the study of cancer at Harvard University are worthy of mention. Many well-equipped laboratories have been built in connection with large universities; while the magnificent gift of the Rockefeller Institute for Original Research affords another example of the influence which these establishments exercise in the development of medicine and surgery. In the Carnegie Institute there is a fund yielding over $300,-000 per year to be expended on its work. In a conservative estimate the property investment in all kinds of medical institutions, such as hospitals, laboratories, medical colleges, health department bureaus, training-schools for nurses, etc., is three or four hundred millions of dollars, not to mention the endowment funds.

That the foundation of medical schools has had a great influence in the history and development of surgery becomes apparent when it is considered that about a hundred years ago there were only 200 medical men in practice in

this country, while to-day there are over 100,000 workers in the field. A century ago our own country could boast of only two small medical schools, while now there are 154 medical schools, affording instruction to 26,821 students annually, many of whom will work in the chosen field of surgery, and nearly all of these medical schools are an integral part of some great university; $418,000,000 scarcely represents the value of the property belonging to medical schools, and $8,000,000 their endowment.

The recent munificent gift by Colonel Payne to Cornell University for the establishment of a medical department in New York City marks a most important epoch in the education of the physician and surgeon in the country. It is a fact worthy of honorable mention that the wealthy men of the present century have contributed most liberally to the science of medicine, as is obvious from a review of the recent different gifts and endowments amounting to many millions, especially during the past few years.

That the establishment of training-schools for nurses has had much to do with the progress of surgery is obvious when it is considered that about a quarter of a century ago there was not an American trained nurse, if any, in the United States. To-day there are about 11,000 pupils, and nearly 20,000 graduates. The inauguration of the first training-school for nurses in the United States at Bellevue Hospital in 1873 marks an important epoch in the history of modern surgery in this country. From the initial school at Bellevue others have been established throughout the country, and now every important hospital in the land has a competent corps of trained nurses as an essential feature of the modern hospital. The far-reaching and widespread influence of the Bellevue training-school, which was the first in this country, to grant a diploma, cannot be overestimated, as it relates to the improvement in the care of

the sick, to the establishment of other training-schools, and to the opportunity offered to make possible the practice of surgery of the present century. The valuable services of Mrs. W. H. Osborn for nearly thirty consecutive years and the untiring labors of Mrs. W. P. Griffin, who has been its faithful president for nearly twenty-one years, entitles them to a high place of honor in the estimation of the medical profession. The progress of surgery in this country has been largely influenced by the help and aid which this department of philanthropy has offered to suffering humanity.

It is indeed a truth that without the Bellevue Training-School for Nurses, and the influences which have sprung from it, the surgery of the present century and notably of the last quarter of a century in America would not have been possible. The lady managers of the noble charity can feel a just pride in the silent and beneficent work which they have accomplished on behalf of suffering mankind, and can feel, moreover, that they have participated in the great work that marks a milestone in the progress of surgical science in the United States.

That medical museums have exerted an important influence is apparent from the fact that a century ago there were none in the land, while now there are many. Not a few of these are admirably equipped and appointed. They contain over 200,000 gross specimens. For their maintenance nearly $200,000 is expended annually, or one dollar each for the preservation of each specimen.

The history of surgery during the past century furnishes one of the most remarkable chapters in human affairs. It is obvious that life is the most important factor and element in the history of the race. Without life, of what avail is all else in the world? Surgery has to do with the saving of human life, and as such is the grandest and

noblest of the sciences, and the most beneficent to mankind. A study of its development brings us face to face with the most startling and miraculous discoveries which have had an influence upon the health, the happiness, and the mortality of the race.

It is only necessary to remember that a little over a hundred years ago there were scenes enacted in the name of surgery which eclipsed in horror the frightful cruelty of the Spanish Inquisition, the untold miseries of the Bastile, the indescribable sufferings of the Black Hole of Calcutta, the excruciating pains of the Turkish bastinado, and the cruel massacre of the Huguenots. One shudders at the horrible cruelties which were perpetrated on withering mortals in the name of surgery. The records of suffering which have come down to us through the years of the century have no counterpart in the various experiences of modern life. Patients were held down upon the operating-table by brute force and were operated upon while in the full possession of their senses; they were heard to shriek and to cry out in heartrending screams for a discontinuation of their tortures; they were incised with red-hot knives, and they were compelled to have their wounds dipped in a caldron of seething tar to control hemorrhage.

Through God's infinite mercy in the progress of the century, all this is now changed. The patient falls asleep without a struggle; and when he awakens to consciousness the operation is finished. The convalescence is fever-free and painless; the mortality is reduced almost to zero in many cases, and the operation itself robbed of all its horrors. The evolution which surgery has made to effect such a wonderful change is one of the most fascinating studies in the world's history.

To dwell upon this in orderly manner is the purpose of the present discourse. In order to simplify as much as

possible the comprehensive subject, it is necessary to divide it into four different parts, and to trace the rise, progress, and development of surgery in its triumphal march as it pertains to these four great events in history, during the past century.

1. The discovery and employment of anesthetics.

2. The discovery and practice of antiseptics.

3. The discovery and application of modern therapeutics and of new diagnostic aids.

4. The improvement of old and the discovery of new operations with their mortality.

1. *The Discovery and Employment of Anesthetics.* Among the important events in the history of mankind which have been far-reaching and beneficent in their influence, the discovery of anesthesia easily stands in the foremost ranks. What greater blessing has science ever conferred upon the human race? Other discoveries and inventions have indeed been revolutionary in their results for social advancement and comfort; but anesthesia outranks them all, in its combinations of kindness and power at a point of unutterable need. This wonderful boon to suffering humanity, now gratefully in use throughout the civilized world, comes from our own land—America. No other nation has presumed to lay the slightest claim to any priority in its discovery. Anesthesia with its world-wide blessings is confessedly American.

In 1844, Horace Wells, a dentist of Hartford, Conn., heard a lecture by Colton on nitrous oxid gas. In illustration of the lecture the gas was administered to a person in the audience. The man fell to the floor; but was insensible of his fall, confessing afterward that he was absolutely unconscious. This episode caused Wells to think that perhaps the gas could be utilized in dentistry for the painless extraction of teeth. With a true courage of his

convictions he tried the experiment upon himself, inhaling the gas, and having one of his own teeth extracted by his assistant. When a few moments afterward, he returned to consciousness, he cried out in his enthusiasm, "a new era has dawned upon the world, I did not feel it more than a pin-prick," and Horace Wells was a greater prophet than ever he dreamed himself to be in the moment of wild excitement.

In 1844, William Morton, a Boston dentist, heard that sulfuric ether could be inhaled in small quantities, and that it produced a certain degree of unconsciousness. Like Wells, Morton immediately tried the experiment upon himself, a daring thing to do. After inhaling the ether he became insensible for eight minutes. The moment he came to himself, the thought flashed through his mind that in ether was a vapor which would produce insensibility for a longer period than gas, and that here was an anesthetic peculiarly suitable for surgical work. Accordingly, he sought his opportunity. It came on October 16, 1846, a red-letter day in the history of surgery, not only in America, but throughout the world. That day Morton administered ether to a patient in the Massachusetts General Hospital, in Boston, who was to be operated upon by Warren for the removal of a vascular tumor. Under the influence of ether the patient remained unconscious during the operation, which was highly successful. To be sure Crawford W. Long had administered ether prior to this time, but Long did not quite trust the evidence of his own experiment, and feared that his success might be due to an incidental hypnotic influence. The work of Jackson should also be mentioned, since as a chemist he made ether; but it was Morton who really proclaimed the discovery of anesthesia in an emphatic way, so as to arrest universal attention, and introduce a new epoch in surgical science.

November, 1847, was another red-letter date in the progress of surgery, for it was then that Simpson, the famous Scotchman, made announcement of chloroform as a valuable anesthetic.

One of the most memorable nights in the history of the world was when Simpson resolved to try personally the inhalation of chloroform. Sitting with his friends, Duncan and Keith, around a supper-table, he proposed a trial of the experiment. The three men, without the slightest adequate knowledge of what the result would be, inhaled the vapor. It was a brave, hazardous thing to do; but they did it. Almost instantly their conversation sparkled with unwonted scintillations of wit and humor; but it suddenly ceased, and a death-like silence reigned in the room. In a few moments the sound of falling bodies might have been heard; and then again all was silent. Simpson was the first to recover consciousness. He says that when he did so, he heard himself saying: "That is good." Then he saw Duncan lying on the floor, sound asleep and snoring; while Keith was struggling to regain the chair from which he had fallen when the chloroform did its work.

That was an historic scene, fraught with inestimable value to mankind. Here were three noble men, brave heroes, every one of them, experimenting at the conscious risk of their own lives, with a vapor respecting whose fatal qualities they knew not, in the hope of discovering a way by which poor suffering humanity might be spared from pain. They took the chance of sacrificing their own lives if necessary, for the good of mankind. Such acts of patient research, weary waiting, unselfishness, bravery, and heroism belong only to a profession in which saving of human life at the risk of losing one's own life is undertaken.

It appears that Simpson's mind had long worked on the great and perplexing problem. His daughter tells us that

"very early in his student days he had so sickened at the suffering he witnessed in the operating-theater that he had shrunk from the scene, decided to abandon his medical studies and seek his way in the paths of law." This, however, he did not do. On the contrary he resolved "to fight a good fight" in the field upon which he had already entered, and he did, getting to himself an undying fame thereby, and conferring an immeasurable benefit upon mankind to the end of time.

Before leaving this part of our subject, it seems pertinent to call the attention of the enemies of vivisection to the splendid heroism and unselfishness which Wells, Morton, and Simpson displayed in making these hazardous experiments upon themselves, and not upon lower animals. This world would be far better off if these enemies to the true progress of surgery would take this noble object-lesson to heart, and cease their senseless tirade against vivisection, which has been as absolutely accessory to science as its benefits have been great. The only object and aim of vivisection is to save man from suffering, misery, and death. Shakespeare's thought that "it is sometimes necessary to be cruel in order to be kind" is true in this connection.

The topic of anesthesia must not be dismissed without a reference to Koller's discovery of local anesthesia by cocain, especially in ophthalmic surgery. The use of the spinal canal for medication, of which the injection of cocain for anesthesia is one of the administrations in vogue, was suggested by Corning in 1884. This particular form and method of anesthesia has been a contribution to surgery within the past quarter of a century, and has met the needs of a class of cases to which general anesthesia could not be applied.

As to the mortality of anesthetics, Poncet concludes that chloroform is more dangerous than ether, since Juillard's

and Gurlt's statistics show one death in from 2000 to 3000 administrations of chloroform, and one death in from 13,000 to 14,000 of ether, while in nitrous oxid gas there are practically no deaths.

The influence of the introduction of anesthetics upon the progress of surgery can be best illustrated by a reference to the statistics of operations recorded in the Massachusetts General Hospital. Halsted has given the figures for 10 years before and 10 years after the discovery of anesthesia, which I quote. During the 10 years prior to the employment of anesthetics, there were only 385 operations performed in the Massachusetts General Hospital, or about 38 annually, or about 3 each month, or less than 1 a week. In the 10 years after the use of anesthetics began, and before the discovery of antiseptics, there were 1893 operations, or say 189 annually, or about 15 every month, or nearly 4 each week. If now the number of operations in the same hospital during the past 10 years is considered, it is found that they amount to 24,270, or about 2427 annually, 262 every month, and about 50 each week, while of those performed in the year of 1903, they number no less than 3109, or about 250 each month, or about 65 each week. What a tremendous advance upon the less than one operation each week of about half a century ago to the 65 each week at the present time in one hospital alone. It must be said, however, that this remarkable increase is largely due to the introduction of antiseptics, as well as anesthetics, in surgical practice. In other words, Hoffman has shown that the increase in surgical operations during the past half-century has been more than six times as great as the increase in hospital patients as determined by the Massachusetts General Hospital. So we are led to the second chief topic of this address.

2. *The Discovery and Practice of Antiseptics equal in Importance that of Anesthetics, and contribute almost as largely to the Progress and Development of Surgery during the Past Century.* This discovery, unlike that of anesthesia, belongs exclusively to no one nation. Pasteur, in France, discovered that putrefaction is due to the presence of bacteria in the air. Lister, in Scotland, applied the discovery to surgery. In Germany and in the United States a yet further application of the technic was made. Antiseptics, therefore, have been an evolution in which all well-progressed countries, notably Great Britain, have taken a part. Lord Lister's discovery will always stand as one of the great milestones in the advance of surgical science.

There are certain remarkable facts connected with the early surgery of this country which clearly foreshadowed the introduction of antiseptics. Absolute cleanliness was a characteristic feature of Mott's surgery. His personal toilet and the cleansing of every instrument before use indicated that he recognized perfect cleanliness as a *sine qua non* to surgical success; also the employment of animal ligatures in this country anticipated their general adoption as an essential part of antiseptic technic. Dorsey, as early as 1844, successfully ligatured large vessels with buckskin and catgut. Hartshorne used parchment and Jameson proposed ligature from deerskin. All these factors, which now are recognized as an essential part of antiseptic surgery were marked steps toward the perfect aseptic technic of today.

The general subject of antiseptics cannot be passed over without a just and generous recognition of Lord Lister's work. It is simply right to say that to him belongs the exclusive honor of having discovered antiseptic surgery. While at Glasgow, in his early professional life, Lord Lister became impressed with "the evils of putrefaction in surgery."

What appalled him in his clinical observations was the difference of healing between a simple and compound fracture. In a compound fracture there was communication between the seat of fracture and the external air. This condition gave rise to suppuration, blood-poisoning, and death. In a simple fracture there was no communication between the seat of fracture and the external air, and the wound healed speedily without suppuration, blood-poisoning, or death. This striking behavior in the action of wounds led Lister to the discovery which has made his work imperishable, and has given an earthly immortality to his name. Mr. Lister believed that the blood in the wound underwent putrefaction in the same way as Pasteur had demonstrated that meat decomposed through exposure to the air. Lister's first endeavor was to overcome the evil by scrupulous cleanliness, just as Mott had done. But he quickly found that this method was inadequate to meet the need. Studying the subject, he immediately realized that Pasteur's theory was correct; that putrefaction was a fermentation produced by bacteria in the air; that these microörganisms could not develop *de novo,* in the putrefying substances; and that there was no such thing as spontaneous generation of bacteria. He also saw that when the bacteria in the air could be prevented from entering the wound, the wound would not suppurate nor give rise to blood-poisoning. He then asked himself the question, how can these bacteria be destroyed, or how can their fatal entrance into a wound be prevented? In other words, how could we kill the bacteria and yet not harm the patient?

This was the problem and proposition. Its solution is antiseptic surgery. Lister had heard of carbolic acid as a deodorizer. As such he applied it, undiluted, to a compound fracture, with repeated renewals. Watching with intense interest the application, he was overjoyed to see

that suppuration was almost entirely prevented and so all fear of blood-poisoning and death removed.

This was, practically, the discovery of antiseptics. A method for preventing putrefaction was found, and in consequence aseptic healing by gradual evolution and by modern improvements followed. No one can measure the vast influence which this wonderful discovery has had upon the human race. It has eliminated local pain in a wound, it has prevented general fever, it has made possible many new life-saving operations, it has saved millions of lives.

The influence of antiseptics upon the increase of surgical operations, and the decrease of mortality attending them, is difficult to estimate. Suffice it to say, by way of illustration, that in the Boston City Hospital prior to the introduction of antiseptics there were, in 1878, according to Halsted's statement, only 132 operations performed, while in the same hospital, in 1903, there were 2719. In the New York Hospital, in 1878, there were 142 operations, in 1903, there were 1680. How different and justly so the prevailing idea of the day as regards the operative part of surgery. Prior to the past century, operations were looked upon as a tacit confession of failure, and such they commonly were. To-day, they are properly recognized as the grand triumph of a new science. These facts tell the story of the progress of surgery more forcibly and eloquently than could be done by any spoken discourse, no matter how carefully prepared.

3. *The Discovery and Practice of Modern and Surgical Therapeutics and of New Diagnostic Aids.* This part of our subject embraces all the non-operative methods of treatment of surgical affections which have been devised during the past century. It is obvious that within the limits of this address mere mention only can be made of the various remedial agencies and the general results which have been obtained by their application.

The Röntgen rays were discovered about 1896, and the civilized world was startled by a discovery which ranks after anesthetics and antiseptics as one of the greatest advances in the science of surgery. Röntgen demonstrated that the Röntgen rays would pass through the human body and throw a shadow picture on a photographic plate. In other words, that the rays had the power to pass through substances which were opaque to ordinary rays of light. Bullets can be seen and located in the body, and bones can be distinctly outlined, because they are denser than the soft tissues. Fractures and diseases of the bones, dislocations and diseases of joints, as well as foreign bodies in the economy, can be observed. Tuberculous processes in the lungs can be distinguished, and the heart can be seen actually pulsating. Gall-stones can be made out in the gall-bladder, and calculi can be detected in the pelvis of the kidney and in the urinary bladder. Sarcoma, myelitis, syphilitic osteitis, bone abscess, periosteal and central origin of bone tumors can be diagnosticated. Carcinoma, tuberculosis, osteoarthritis, osteoporosis can be made out with distinctness. Brain tumors, notably gumma, Hodgkin's disease, aneurism of the large vessels, and glandular enlargements and growths in the mediastinum can be demonstrated.

The Röntgen rays have also been used with a view to the cure of certain malignant diseases, notably cancer of the skin and sarcoma, especially when the disease cannot be treated by ordinary means. It does not appear to have been of any special value in other forms of cancer located in the organs of the body. The Röntgen ray has also been employed as a depilatory, also to bring about atrophy of the glands of the skin and to relieve pain. The Röntgen ray also is used to cure pseudoleukemia and splenomedullary leukemia, rodent ulcer, lupus vulgaris, and chronic eczema.

Great credit belongs to our distinguished chairman for the magnificent work which he has performed in the application of the Röntgen ray to surgery, and his writings upon this subject are worthy of close study.

The *Finsen light* is a discovery which was made about 1897, by means of which certain forms of cutaneous disease of an infective origin, notably lupus, have been cured. This result is accomplished by means of a light which can be employed without accompanying heat, and which causes an inflammation of moderate intensity upon the skin. Sunlight fails to destroy bacteria, owing to the presence of heat, while the Finsen light, deprived of heat, effects a cure.

In 1878, Blunt and Downes proved the efficacy of chemic rays of light to kill bacteria. Finsen demonstrated that the action of light was increased if it be applied through rock-crystal lenses, and the heat absorbed by passing it through a violet-colored liquid and water, while the part of the body to be treated is made anemic by pressure. Finsen apparatus increased the efficacy of the violet or chemic rays, and absorbed red or heat rays. The effect of light upon bacteria is slow in its operation, but its rapidity is increased by concentration, by means of mirrors or by lenses. The heat-rays, such as ultra-red, red, orange, or yellow, must be eliminated, as they burn the tissues, while the blue or violet rays destroy the bacteria. The arc electric light comes next, and is now often used because it can be obtained at all times. The incandescent light is of no value, owing to the fact that it possesses too few chemic rays. The electric light requires a special apparatus for its use, since its rays are divergent and not parallel, as is the case in the sun's rays. Professor Pupin says that the time is not far distant when a new method of producing light of short wave-length will be perfected, which

will be far more powerful than the Finsen light. The shortcomings of the present method of producing light of great actinic power consist principally in the absorption of this light by the glass of the vacuum tubes in which it is produced. Within the last year a method has been discovered of fusing quartz, and blowing it out by means of the oxyhydrogen flame into bulbs, which are used for electric vacuum tubes. Quartz, as is well known, absorbs light of short wave-length to a very slight extent, and it is the light of short wave length which is employed at the present time for therapeutic purposes. When this discovery is applied to surgery, the field of usefulness of light as a remedial agent will be greatly enhanced, and without doubt many new diseases will be relieved that the present Finsen light fails to cure. The results of treatment of lupus by the Finsen light are interesting. In 456 cases in which the treatment had been completed at the end of 1900, no fewer than 130 are known to be free from recurrence for from one to five years. In the rest of the cases the period of cure is too short to establish any reliable data. In 44 cases of lupus erythematosus, 14 were reported cured and 15 improved. In 49 cases of alopecia areata, 30 were reported cured. In 24 cases of rodent ulcer and cancroid, with 11 favorable results. In 25 cases of acne vulgaris, 13 were cured. These statements give an approximate idea of what has been accomplished in a short time by Finsen light, and, without doubt, improvement in the technic will result in even a greater number of percentages of cure.

Radium is a new element which was discovered in 1899 by Madame and M. Curie. The term "radium" is derived from the Latin word *radius,* meaning a ray. At the present time there is great interest in the question of the therapeutic use of this metal, but sufficient time has not elapsed to determine its value.

Radium is a new therapeutic agent which has recently been used in surgery, and furnishes a new illustration of the development of the science. Radium as a therapeutic possibility is little understood, but about which much has been written. The public press has been flooded with sensational articles about radium, while the medical press has been conspicuous for the meager accounts of its therapeutic uses.

The action of radium depends upon its "spontaneous source of energy" upon living tissues. The action of radium upon the tissues is very similar to the Röntgen rays, and its use is indicated in those cases in which the Röntgen ray is applicable. Radium as a therapeutic agent depends upon its radiations, which are of three kinds, and have been designated by the terms Alpha rays, Beta rays, and Gamma rays. The Alpha rays consist of a current of electric charge that contains an amount of energy far greater than the Beta rays or the Gamma rays. The velocity of the Alpha rays is said to be 20,000 miles per second. Ninety-nine per cent of the energy of radium is in the Alpha rays. The Beta rays consist of a negatively charged stream of particles very similar to the cathode. The Gamma rays travel with tremendous velocity and are similar to the Röntgen ray from a hard tube. The Alpha rays have very slight actinic properties, while the Beta and Röntgen rays are highly actinic, and are therefore the rays used in therapeutics. Beta rays do not penetrate the tissues deeper than half an inch, while the Röntgen rays from the pure radium pass through the body. Radium gives off heat and a gas called helium, but these properties have no influence in the therapeutic action of radium. Radium destroys bacteria and affects the metabolism of cells and is used in the treatment of certain skin affections, notably lupus, keloid, nevi, rodent ulcer, epithelioma, carcinoma,

and sarcoma. The action is similar to the Röntgen rays, but the chief advantage of radium consists in a precise estimate of the dosage, while the Röntgen ray, on the other hand, is a more powerful energy, but it is difficult to estimate its exact strength.

Electricity has had great influence in the development of surgery during the past century. It has been employed in many ways, both as a diagnostic aid and as a means of cure. The electric light is used as a means of diagnosis to explore the hidden parts of the body such as the throat, larynx, esophagus, and stomach, also the bladder and the intestinal canal. Perhaps one of the most useful purposes to which electricity has been employed in a diagnostic way is illustrated by the cystoscope by means of which the interior of the bladder can be explored with a view of determining the exact nature of the lesion, the shape and anatomic relations of a growth, or the presence of a foreign body in the hollow and heretofore impenetrable viscus. The stomach also has been explored with a view to determine the nature of the lesion. It is also used to test the contractility of muscles which should respond quickly to the faradic current if the nerve is diseased. In this way the surgeon can diagnosticate functional or organic disease of the nerve by the behavior of the muscles when the electric current is applied. The electric current is used in surgery as a curative means in the removal of small malignant growths and nevi, to arrest primary hemorrhage in places when the ligature is inapplicable, or secondary hemorrhage where compression is not admissible. In the form of an *écraseur,* electricity is used to remove pedunculated tumors, to cauterize long sinuses, to arrest suppuration in the eye-ball, to sterilize the pedicle after appendectomy, ovariotomy, or hysterectomy, to cause coagulation of blood in the treatment of aneurism, to overcome obstruction in

the eustachian tube, to find bullets imbedded in the human body, by a probe which was invented by Girdner of New York, to stimulate muscles and nerves, to improve the circulation of the blood, and even to relieve severe pain.

Serum therapy is a newly discovered method for the treatment of certain surgical diseases, among which may be mentioned hydrophobia, tetanus, acute phlegmonous inflammations, anthrax, and other infectious processes. The history and development of surgery during the last quarter of a century would be incomplete without a reference to the inoculation method to prevent certain surgical diseases. The principle involved in this system is the one enunciated by Pasteur, to whom the world owes an everlasting debt of gratitude. In 1880, Pasteur announced to the French Academy of Science that he had discovered a method of inoculation, by means of which he could reduce the virulence of a disease caused by a special germ. An attenuated virus of the germ-disease was inoculated into the system of a susceptible animal, and this infection would give rise to only a mild attack of the disease. The attenuation of the virus, as Pasteur termed it, was accomplished by cultivation of the special germ in certain mediums exposed to the air. His research up to this time was limited to chicken-cholera; but he announced that in the future he believed that the great principle of inoculation would extend to other diseases. In 1881 he proved to the world the correctness of this view by announcing his cure of anthrax, that fatal malady affecting sheep and cattle. The world was skeptical of his discovery, and the president of the Agricultural Society of France urged Pasteur to make a public test of his cure. To this proposition Pasteur, in the true spirit of scientific faith, assented, because he was fully convinced of the truth of his theory. Fifty sheep were supplied by the president of the Agricultural Society

for the test. To this flock Pasteur requested that 10 cattle be added and 2 goats be substituted for 2 sheep, with the understanding that failure in his experiment with cattle and goats must not invalidate the test, since he had never carried on experiments with cattle or goats. The acceptance of this challenge by Pasteur was a brave act; because he knew if he failed in this public experiment the world would denounce and deride him. The inoculations of the attenuated virus of anthrax were then made on 24 sheep, one goat, and five cattle, at certain intervals upon three successive occasions. After a proper time had elapsed the 60 animals were inoculated with a culture of the anthrax microbe. Forty-eight hours after this injection of the full-strength virus into all the animals, the public gathered to witness the success or failure of this most wonderful experiment in the scientific world. The sight that the eyes of the vast crowd beheld beggars description. In the paddock were seen dead or moribund every animal that had not been previously inoculated with the attenuated virus. In this same paddock were seen the remaining animals that were inoculated with the attenuated virus walking about apparently in perfect health. This paddock formed a veritable arena in which was witnessed the greatest battle that science has ever fought. The victory was complete, unequivocal, and overwhelming. This successful experiment established a new epoch, and this new principle was soon applied to certain human diseases.

In 1885 Pasteur proved the value of this method in the treatment of hydrophobia. In this latter disease the virus of rabies was inoculated into guinea-pigs or rabbits, and an attenuated virus was made from the spinal cord of these inoculated animals. The mortality of hydrophobia by Pasteur's treatment, by Celli, of Rome, has been only 5%, since 1899, at which time the institute was built and organ-

ized, and during these four years 2000 patients have been treated with the serum.

The value of serum therapy is shown by a reference to the work of the lamented Walter Reed, of the United States Army, who discovered a treatment for yellow fever, a disease which destroyed over 80,000 persons in this country during the past century. To-day this scourge has been wiped from the face of the earth. The bubonic plague, the most frightful disease that could visit a country, created panics among the people in former years; but now, owing to the efficacy of serum therapy, its entrance into this country creates only a passing comment. Even in New York the disease was observed at quarantine, and was stamped out immediately. Thompson predicts before long that the bubonic plague, which is now practically confined to the valley of the Euphrates, will be annihilated from even that locality, as well as cholera from the valley of the Ganges. Haffkine's serum for the treatment of this bubonic plague reduced the susceptibility of those exposed to the infection 75%, and the mortality by 90%.

Gilman Thompson says that "thirty years of bacteriology in all of its applications have done more for mankind than all the medical research that has preceded. In an estimate made by Alfred Russell Wallace of 25 discoveries of world-wide importance made during the nineteenth century, a fifth were contributed by medical science, and all but one of these were made during the last half of the century. Two more have been greatly influenced by medical science, viz., the theory of the antiquity of man and the doctrine of organic evolution. Yet we have not wholly emerged from the shadows of the Middle Ages, for have we not still among us those who fain would abolish such experiments as have made possible discoveries like those of vaccine, antitoxin, and antihydrophobic inoculations, even as

there are those in Persia who would mob physicians seeking to check the spread of cholera?"

Tetanus is a surgical disease which baffled the skill of physicians for centuries. Recently it has been treated with very encouraging results by means of antitoxin. This method of serum therapy, together with the application of antiseptic surgery, has yielded results that offer a striking illustration of the onward march of surgery. In olden times the mortality in tetanus, according to Lambert was 80% for acute cases, 40% for chronic cases, and 60% as an average for all cases. The mortality in tetanus, treated by antitoxin and by antiseptic surgery, was about 61% for acute cases, and 5% for chronic cases, and 30% for all cases.

From these statistics it is evident that antitoxin has reduced the mortality half, and if the antitoxin were properly used, the mortality would be much less than half. The reasons why antitoxin has no better statistics at the present time are because the antitoxin has not been pure or long enough continued, or not in sufficient doses, or too late in its administration. If properly used, the reduction in mortality would be striking, and from now on the results will be entirely different. Antitoxin has its widest field of usefulness as an immunizing agent. All surgeons agree that it would not be justifiable to immunize a patient on the vague supposition that tetanus might develop. The use of the antitoxin as a prophylactic measure is consequently limited to those cases where the wound has been inflicted in such a manner as to allow garden-earth, plaster from walls, or manured soil to come in contact with it, or where the traumatism has been caused by a rusty nail upon which the bacilli are discovered, or in a given locality where tetanus is prevalent, or where the wound is a lacerated one with entrance of foreign bodies into it. In these cases Murphy

states that the injection of antitoxin has reduced the mortality 50%.

Bazy, a French surgeon, had four fatal cases of tetanus in his practice in one year, and subsequently began injecting 20 cc. of serum into all patients who suffered from lacerated wounds, into which extraneous matter had of necessity entered. Since he adopted this practice, tetanus has not followed in those cases in which a strong probability existed that this dreaded disease might develop. Lambert mentions that Nocard, in veterinary surgery, immunized 375 animals, and in no single case did tetanus develop, while he had 55 cases of the disease in non-immunized animals in the same environment. Antitoxin does not affect in any way the life of the bacilli of tetanus, or the spores. Both the bacilli and their spores, when they penetrate the tissues by a wound, live for days and weeks. In these cases, when antitoxin is given for the purpose of preventing the symptoms which would be caused by the toxins during the first few days, it will destroy the action of the toxins. If, however, some of the spores remain quiescent, they may only develop into bacilli at a time when the antitoxin has been eliminated, and if they then develop into bacilli the toxins produced will be absorbed, and cause symptoms just as if they had received no immunization dose of antitoxin. For this reason, the immunizing dose should be repeated after the first week, and even after the third week.

Antitoxin as a remedy during the progress of the disease has an important influence upon tetanus; but not to the same extent as when employed for immunizing purposes. Welch believes that the longer the period of incubation, the better will be the results from the use of antitoxin, and that this remedy is of little value with a short incubation period, that is, less than seven days. When antitoxin is

used under these circumstances, it should be continued long after the symptoms of tetanus have subsided. Lambert has also called attention to a most important point in the treatment of tetanus, and that is, the great care the surgeon should exercise after all symptoms have disappeared. For example, absolute quiet should be insisted upon long after the patient has become convalescent, since he knows of five deaths recently in New York City where the patients were awakened suddenly out of a sound sleep, and a convulsion was brought on from which the patients died.

Antiseptic surgery plays an important rôle in the treatment of tetanus, since it has been shown that in the majority of cases of tetanus the infection proceeds from the development of the spores rather than from the bacilli. It has also been demonstrated that the spores develop better under special circumstances of a mixed infection, and, therefore, all tetanus wounds should be made aseptic in order to destroy the microbes of suppuration, notably the streptococci and the staphylococci. It often happens that the wound is situated on an extremity, notably on the finger or toe, and the question arises as to the propriety of amputation of the affected part. This operation is of no avail unless the sacrifice is made immediately after the infliction of the injury, but it is indicated if the wound cannot be thoroughly disinfected. It is better to live without a finger or toe, or even a leg, than to run the risk of tetanus with its attendant suffering, which leads in the acute cases so often to death. The small punctured wounds, which may seem insignificant, should be incised deeply, thoroughly cleansed, and then properly drained. The toxins of tetanus are chiefly eliminated by diuresis. To best utilize this channel of elimination the imbibition of large quantities of fluid is indicated. The saliva has also been said to be a channel of elimination. The function of the skin has

not been proved to be of any avail in eliminating the poison. The employment of anodynes forms also a prominent part of the treatment. This step, therefore, should not be overlooked, since it is clearly proved that much suffering can be relieved by certain drugs. Among the drugs that are found to be most useful are chloroform, morphine, chloral, bromides, physostigmin, antimony, and nitrate of amyl. Chloroform is a most valuable remedy, because it relieves the intense suffering and diminishes the intensity of the spasm and also prevents suffocation. This agent must be used with every precaution and with every stimulant present, and ready for immediate use. Statistics show that when chloroform was employed in the treatment of tetanus, the mortality was 10 per cent less than in the cases when the drug was not employed. Thus it is evident that the use of antitoxin, the employment of antiseptic surgery, the administration of certain anodynes and the enforcement of quiet to avoid reflex disturbances, comprise a plan of treatment which will offer brilliant results in the cure of this terrible malady. The success of this treatment in tetanus alone is a monument of the progress which surgery has made during the past quarter of a century.

The antitoxin treatment of diphtheria affords the most forcible illustration of the value of serum therapy in the treatment of infectious diseases. This disease does not, strictly speaking, belong exclusively to surgery; but it affords an opportunity to show the results of the use of antitoxin, and it often happens that the disease may require surgery for its relief. From the statistics of the Health Board of New York City prior to January 1, 1895, the mortality was as high as 64%, and in 1902, as a result of the use of antitoxin, mortality was reduced to 9.5%. From a period of 5 years, from 1888 to 1894, the mortality was from 64% to 44%, and the following 4 years, from 1895

to 1898, the mortality dropped to 12%. In 1902 the mortality was reduced to 10.9%. In another series the cases were also not selected. They were collected from hospitals, asylums, private residences, and many of them were moribund at the time of the use of the antitoxin, and the mortality was less than 8%, as contrasted with 64% to 44% 20 years ago, or before antitoxin was employed. In 1903 the improvement was still greater, since in 1208 cases of diphtheria only 72 died, thus giving a mortality of only 5.9%. If the 26 moribund cases were deducted, the mortality is only 3.8%. There remains no longer any doubt as to the value of serum therapy in this disease, and if these results can be taken as prophetic of the result of serum therapy in other infective diseases a new era has dawned upon the civilized world. Billings has called attention to one fact, and that is the necessity of the early administration of the antitoxin, since in 1702 cases injected on the first day, only 85 patients died including the moribund cases; the mortality was only 4.9%. Finally, in 1610 cases collected from 12 physicians in private practice, and not including the moribund cases seen in consultation, there were 24 deaths, or a mortality of only 1.5%. An antitoxin has been made by Calmette, who worked in the Pasteur Institute, to prevent death after the bites of venomous serpents. This antitoxin has already afforded immunity to thousands of persons who had been poisoned by the bite of venomous reptiles in India and Australia.

The antitoxin treatment of snake-bite was discovered by Vital, of Brazil. He made some extensive experiments with antitoxin at the institute over which he had charge. This serum was better than the control tests with Calmette's anti-venom serum. Vital called the serum anti-ophidic, and he reported 21 cases of bite of venomous reptiles with recovery, without any appreciable clinical symptoms. The

strength of this anti-ophidic serum is shown by the fact that even a fraction of a milligram of the snake-venom causes severe symptoms to appear when injected into lower animals. In three of the 21 cases, the symptoms appeared almost immediately after the bite of the snake, and were most pronounced in type. In these three cases, however, 20 cc. to 60 cc. of the antiophidic was injected and recovery took place, notwithstanding two hours had elapsed in one case, and three hours in another case. Vital has also prepared a special serum for the bite of rattlesnakes.

In India, 22,000 persons and 60,000 cattle die each year from the bites of the poisonous ophidia. Many of these deaths can now be prevented by inoculation of the antivenene. In tuberculosis the mortality has been reduced 50%. Koch's wonderful discovery is an enduring monument to his greatness. In Germany alone 90,000 persons die annually from tuberculosis. This gives us an idea of the far-reaching influence of Koch's marvelous discovery.

Blood analysis has had much to do with the development of surgery, and affords a most valuable diagnostic aid. Without this contribution from the science of hematology the development of surgery would never have reached its present state. This is not the place to enter upon any discussion of blood analysis except as it pertains to surgical diagnosis, by means of which the broad field of operative surgery has been enlarged. In speaking of blood analysis a reference only will be made to the influence it has upon operative surgery. Blood analysis makes certain the diagnosis in some surgical diseases, it aids in the diagnosis of other diseases, and it helps to diagnosticate a condition, where from unconsciousness, inability to speak, insanity, or malingering, a history is unattainable. The chief points to ascertain are the number of erythrocytes, the leukocytes, the ratio of one to the other, the number

of blood plaques, and the ratio to each other, the size, form, and contents of the blood-cells, the amount of hemoglobin and of fibrin, the specific gravity of the blood, and bacteria contained in it. The erythrocytes or red blood globules normally exist in the blood in the proportion of about 5,500,000 in a cubic millimeter. The term oligocythemia indicates a deficiency in the number of red blood globules, or a diminution of their relative proportion. The term poikilocytosis indicates an irregularity in the shape and size of the globules, and an increase in the red blood globules is called polycythemia. Now oligocythemia is observed in hemorrhages, anemia, etc. Polycythemia is observed in cases, where there is a loss of fluid from the blood as in cholera, severe diarrhea, etc. The leukocytes or white blood globules normally exist in the blood in the proportion of about 7500 in a cubic millimeter. An increase of 1500 or more in the number of the white cells indicates a condition known as leukocytosis.

Now, a normal leukocytosis is observed in health after meals, during pregnancy, following violent exercise, a cold bath, and massage. An abnormal leukocytosis is observed in such diseases as erysipelas, osteomyelitis, suppuration, malignant tumors, and in pneumonia. The term leukemia indicates a permanent leukocytosis. In the differential diagnosis of surgical affections, blood analysis is of great assistance. For example, in shock from hemorrhage there is oligocythemia. In shock from concussion or compression of the brain, there is no decrease in red blood cells. In appendicitis and pus tubes, there is a leukocytosis, while in floating kidney, ovarian neuralgia, gall-stones, renal and intestinal colic, it is absent.

In meningitis, in cerrebral abscess and cerebral hemorrhage, there is leukocytosis, while in other intracranial lesions it is absent. In all forms of sepsis, leukocytosis is

present. Blood plaques normally exist in the blood in the proportion of 200,000 cm. to 500,000 cm. In disease, the plaques are increased.

Hemoglobin normally exists in the blood in about 90%, and below 20% is the minimum in life. The relation of hemoglobin to the erythrocytes and the rapidity with which it regenerates after injuries, surgical operations collapse, and hemorrhages, enables the surgeon to determine the prognosis. Syphilis and cancer retard the regeneration of hemoglobin, while tuberculosis, curious to state, increases the regeneration. In operation for removal of cancer, for example, the amount and rapidity of regeneration of the hemoglobin enables the surgeon to determine whether complete removal of the malignant tumor has been accomplished, and whether the rapidity is sufficient to justify the conclusion that perfect health can be reinstated.

4. *The Improvement of Old and the Discovery of New Operations with their Mortality.* It is obvious that a consideration of this part of the subject can only embrace a cursory review of the field of operative surgery. No attempt will be made to describe in detail an operative procedure. A mere reference to the improvements in old operations and the discovery of new operations will be made as affording tangible evidence of what surgery has accomplished for mankind. The operations that have been discovered and performed within the past 100 years will be mentioned, and an endeavor will be made to show to what extent the science of surgery has been a benefaction to the human race. In order to demonstrate this proposition, it is necessary to record the date of the first performance of each prominent operation, and then to show what result has been accomplished since its introduction. In this way an idea can be obtained of the value of each great operation, and the advance which each has made toward saving

life. A review of this kind naturally is devoid of popular interest, but at the same time these important factors are worthy of record and study. In this way only can the true progress of surgery be measured, since the operations performed prior to the past century are insignificant and unimportant. It is only by a study of the operations of the past century that the magnitude and usefulness of modern surgery become impressive and apparent. If what has been accomplished during the nineteenth century be taken from the sum total of knowledge of surgery, nothing will be left to entitle surgery to a recognition among the sciences. The work accomplished with the century, however, as a study entitles surgery to a prominent place among the sciences.

The important operations will be considered in the following order: Those belonging to the cranial, thoracic, and abdominal cavities, and finally those of a miscellaneous nature.

External to the cranial cavity, the operation for the cure of racemose arterial angioma, aneurisms of the scalp, sinus pericranii, dermoid cysts, sarcoma, and carcinoma, are among the recent operations that indicate the extension of surgery in this department. The improvement in the technic of the operation for compound fractures of the skull, fractures of the base, encephalocele, and within the cranial cavity, the operations for the relief of hydrocephalus, compression of the brain, ligation of the middle meningeal artery, are worthy of mention, as denoting the progress which surgery has made within recent years. Abscess of the brain has been recently treated with success. Delvoie cites 21 cases of trephining for acute cortical abscess, with 15 recoveries, and 33 operations for chronic deep-seated abscess, with 19 recoveries. In cerebral abscesses secondary to otitis media, Ropke reports 142 cases,

59 of which recovered, and 40% were permanently cured. Frontal abscesses of nasal origin have been operated upon with brilliant success. This life-saving operation which has resulted in cure, until recently hopeless, indicates the progress of surgery. In thrombosis of the intracranial sinuses with operation, results have been obtained. Thus Macewen had only 8 fatal cases in 28 cases. For the cure of infective thrombosis, all of which die without surgical intervention, this is a remarkable showing for this new operation.

Intracranial tension has very recently become a new indication for operative interference. This operation affords relief in a class of cases that heretofore were fatal. This operation is a contribution of modern surgery, and is another milestone which marks the progress of the science of surgery. The recent advances in clinical medicine and clinical microscopy have opened up the heretofore unexplored field for operative interference. Cases of coma with no external injury of the skull have heretofore been treated by the expectant plan, with almost uniformly fatal results. Surgery owes much to these two departments of medicine for valuable knowledge upon a subject which is comparatively new, and which offers an additional field for operative work. Intracranial tension is a condition which a study of modern pathology has shown calls for surgical interference. Intracranial hemorrhage is one of the most frequent causes of intracranial pressure. It may also be caused by bone, pus, and foreign body. In order clearly to understand the theory of intracranial pressure, it is necessary to bear in mind two facts: (1) that the brain itself is incompressible; and (2) that the cranial cavity itself is incapable of expansion, therefore, the pressure of a clot of blood or a fragment of bone, or a collection of pus, or any foreign body, must be accommodated in the

limited space in which the brain is lodged. If the foreign body is of sufficient size to fill the intracranial space by a twelfth, death results.

The treatment of intracranial tension is a new subject, and one which I have of late given special study. I am convinced that operative treatment is indicated in many of these cases. I have employed this measure with most gratifying success. The indications for operative interference are in some cases perfectly clear, while in others the phenomena present would not justify resort to so severe a measure. The greatest difficulty is to determine what the line of demarkation is between the cases that demand trephining of lumbar puncture, and those in which the plan of expectancy can be adopted.

These cases of intracranial tension can be divided into two classes as regards operative interference. The first class includes those in which intracranial tension is sufficient to produce profound coma. Operation will save patients included in the first class that uniformly died under the expectant plan of treatment. Operation will save the patients embraced in the second class when the symptoms are gradually increased in severity. In regard to the indications for operation to relieve intracranial tension in those cases included in the second class in which coma is not present, the problem is difficult of solution. I have been guided as to the operation by the condition of the patient after a study of the symptoms from hour to hour and from day to day. If the arterial pressure arises to a point and remains stationary, and the vasomotor system does not fail, even with a well-pronounced vagi disturbance, no operative procedure was practiced, and recovery has taken place. In addition to the symptom of increase of arterial pressure, the blood-count must be studied, the eye-grounds examined, the urine tested, the reflexes studied,

the disturbances of cranial nerves noted, and all other phenomena investigated. If the pressure is not daily increasing, and the leukocytosis not rising, the red blood cells not increasing, and the urine not becoming glycosuric, the hebetude not emerging into coma, and the cephalalgia not increasing, delay in operative interference is indicated. If all the above-mentioned symptoms from a stationary point begin to increase, operative interference is called for to save the patient's life. If on the other hand, from this stationary point, all the symptoms show an improvement, operation can be deferred at least for the present, if not permanently.

The operation for relief of insanity is worthy of consideration. Surgery has accomplished great victories in the restoration of reason in the insane, when the lesion was due to traumatism. A little over a hundred years ago the management of the insane was most revolting and brutal. In Europe the treatment of the poor outcasts was a blot upon the civilization of the world. Imagine these poor wretched creatures consigned to dungeons and manacled by chains for years. In these dark prisons, the insane, considered as demons, were kept in irons and squalor and filth. It has been stated that the iron tether was so short that these poor unfortunate victims could not even stand upright and were held for years by chains riveted around the neck or waist. The humane treatment of those poor unfortunate people began about a century ago and great credit is due to neurologists who have rescued these sufferers by throwing aside their manacles, by restoring to them their liberty, and by proffering them treatment. Men like Tuke and Pinel and Rush took the initiative in this great reformation. As soon as a rational, humane, kind treatment was instituted, it became evident here and there that among these insane, epileptic demons as they were called, there

were some who could be relieved and sometimes cured. Surgery has been employed for this purpose, and some of the results are almost miraculous.

In the course of the development of surgery, operations have been devised for the relief of insanity where the etiology was due to pelvic disease. In DaCosta's monograph it is mentioned that Hobbs operated on 116 cases of pelvic disease in the insane, with a mortality of the operation less than 2%, and recovery from the insanity in 51%, and great improvement in 7%. "In the group of non-inflammatory troubles, tearing of the perineum, uterine displacements, tumors, etc., 25.5% regained mental health, and 31% improved."

In the surgery of the heart great progress has been made. Bimanual massage of this organ has been successfully resorted to by Cohen in a case of collapse following chloroform narcosis and during laparotomy. In a case described by him: "Artificial respiration for two minutes having no effect, he introduced his hand into the abdominal cavity, pushed along the anterior abdominal wall until the diaphragm was reached, and placing the hand, palm upward, in about the position the heart would normally be, that organ was freely grasped through intervening diaphragm. There was an entire absence of heart action. Placing the right hand over the precordial region, externally, he now plainly palpated the heart as it lay between his hands, and began rhythmic compression, using both hands at a rate of about sixty a minute. After about thirty seconds a slight beat was felt by the left hand. The heart now began to beat slowly, gradually increasing in strength and rapidity until at the end of a minute the beats registered about eighty, and respiration began to be partially reëstablished. About two minutes after this, respiration was normal, pulse 80, and shock being apparently recov-

ered from, the anesthetic was changed to ether, and the operation finished in about thirty minutes, with recovery of patient."

For the relief of pericardial adhesions, a new operation has been devised by Peterson and Simon. This operation is analogous to Estlander's operation for pleuritic adhesions. The operation consisted in a resection of a portion of several ribs, and in some cases a part of the sternum. Murphy cites the fact that of 38 cases of stab-wound of the heart, 90% were penetrating, and only 19% were immediately fatal, thus leaving 81% of the cases amenable to surgical treatment. This new operation, the outgrowth of modern surgery, will afford a new field for this science to save human life in a class of cases heretofore fatal.

In addition to the surgery of the heart, there are many other operations of the chest that deserve mention as indicating the progress which surgery has made within the past century. In surgery of the chest the wounds of the pleura and lung have been successfully treated since the introduction of antiseptic surgery. Abscess of the mediastinum, caries, and necrosis of the ribs and sternum, tumors of the chest-wall actinomycosis, and other infective processes, removal of fluid from the pleural and pericardial cavities, are among the recognized operations of the day.

Wounds of the heart during the past century, and especially during the past 10 years, have been treated surgically with remarkable success. Stewart reports that Roberts, in 1881, suggested the propriety of suturing these wounds. Tillmann believed in the hopelessness of this procedure, yet in 1897, Rehn published the first successful case of cardiorrhaphy in man. Stewart likewise has operated with success, and he has collected 60 cases with the brilliant result of 38.3% of recoveries.

In the surgery of the lung advance has been made within

the last quarter of a century. The diseases of the lung which have become amenable to surgical treatment are tumors, tuberculosis, abscess, gangrene, hydatid cysts, actinomycosis, and bronchiectasis. Murphy has collected 47 cases of tuberculosis; 26 patients were improved and 19 died; 8 cases of actinomycosis, in which the patients recovered; 96 operations for pulmonary abscess, with 80% of recoveries; 122 cases of pulmonary gangrene, with 66% of recoveries; 57 operations on bronchiectasis, with 60% of recoveries, but only half permanently cured; 79 cases of hydatid cysts of the lung, with about 90% of recoveries. In some 400 cases of pneumotomy collected from various sources by Murphy there have been about 300 recoveries, or about 75%. This is a most remarkable result in a department of surgery that has developed within a few years, and includes a class of cases that were formerly practically hopeless. Much credit is due to Murphy for his work as a pioneer in thoracic surgery. Perhaps one of the most interesting operations in connection with pulmonary surgery refers to tuberculosis of the lungs. In reference to excision of tuberculous foci, Whitacre has shown that in nearly 98% the operation is "impossible and irrational." In only 2% of the cases can surgery afford relief, and in these cases the foci are located in the apices of the lung. It is thus evident that there is little to be expected in the future as regards pulmonary surgery as it refers to tuberculosis, since careful investigation has demonstrated the fact that, as a rule, the tuberculous foci are not accessible to the surgeon. Before dismissing this subject the nitrogen compression method introduced by Murphy deserves recognition. The object of this method is to compress the diseased lung by gas, thereby restraining its movement to cause a mechanical obliteration of the cavity and the limitation of the already existing focus, to favor fibrosis, thereby

closing in the avenues of dissemination to afford rest to the affected part in the same manner as a splint to a fractured bone. In certain judiciously selected cases this method is applicable.

In October, 1842, Sayre made a free incision in the chest in a case of empyema, and the patient made a good recovery. Forty-eight years ago Sayre raised the inquiry, "In the empyema of a tuberculous patient from the rupture of an abscess into the pleura, should we not be justified in tapping as soon as discovered?" In 1850, Dr. Henry Bowditch suggested and practiced paracentesis thoracis. Wyman, unaware of Bowditch's operation, performed the same operation. For a long time in this country, as well as in Europe, paracentesis thoracis was condemned; but at last the operation has advanced to the stage of full acceptance by all surgeons. It is almost impossible to estimate the number of lives saved by this operation, but the number is very great, and this operation forms an enduring monument to the fame of American surgery.

Surgery of the stomach has claimed attention only for the past quarter of a century, for previous to that time it was practically unknown. The unsatisfactory state of the surgery of the stomach previous to 1875 is best illustrated by a reference to statistics. It has been shown that of 28 operations attempted upon the stomach, there were 28 deaths, or a mortality of 100%. From 1875 to 1884, improvement took place in that 163 operations were performed with 133 deaths, or nearly 82% mortality.

The reduction of the mortality of 100% to 82% was a gain in the right direction; but it left much to be desired. The rapid strides which scientific surgery has made in the operations upon the stomach forcibly illustrate what can be expected in the future in this department of surgery. There are at present about 12 recognized operations upon

the stomach, and in 7 of these there is practically no mortality, while in the remaining 5 it has been reduced to about 25%. Keen predicts as technic improves the mortality in the most difficult operations ought not to be higher than 10%.

I should predict, from an examination of late statistics, that even less than 10% has already been accomplished, and in the future the mortality will be still lower. Mayo has shown that in an investigation of over 900 operations upon the organs contained in the upper abdominal zone there existed a relationship between gall-bladder and ducts, the duodenum, the pancreas, and stomach. In other words, that the continuity of tissue like the mucous membrane makes the disease of one organ a menace to the others. Mayo also believes that the duodenum, on account of its situation, acts as a buffer, and is involved secondarily in about an equal proportion of cases from gall-bladder disease and gastric ulcer, in the same way Mayo pointed out that diseases of the pancreas were secondary to gall-stone diseases.

Cardiospasm, in which there is difficulty in deglutition from a spasm of the muscles of the cardiac end of the stomach, forms a new indication for operation. It is comparable to pyloric obstruction, and the operation for the relief of cardiospasm is similar to that of pyloric stenosis. Mikulicz and others have performed this operation with brilliant results and effected a cure that could be obtained only by surgery.

Pyloric stenosis is another and new indication for operative interference to relieve the distressing symptoms so often disguised under the term of dyspepsia. In 1901 Roswell Park collected upward of 40 cases in which the patients were cured by surgery.

Gastroptosis is a prolapse of the stomach due to relaxa-

tion of the ligaments which support the organ. This condition gives rise to ordinary signs of dyspepsia accompanied by acute pain and later emaciation. Modern surgery in its evolution has devised an operation for the relief of this distressing and painful condition. The stomach is elevated and held in its anatomic position by shortening of the gastrohepatic and phrenic ligaments of the stomach. Thus the normal ligaments are shortened and the stomach held in its proper position without disturbing its mobility or function. In eight cases reported, including four by Bier, seven patients were cured and one improved. This is a new operation of modern surgery calculated to relieve a distressing condition for which medical treatment was of no avail.

Dilation of the stomach has been operated upon with a view of relief of distressing symptoms to which it gives rise. The operation is called gastroplication and consists in reducing the capacity of the dilated stomach by tucking in folds of the stomach wall. It is a most satisfactory operation, provided there is no pyloric obstruction present. The operation is safe and effects a permanent cure.

Exploration of the stomach has been resorted to successfully by Dennis to relieve hysteric vomiting. Hysteria, as is well known, gives rise to persistent and uncontrollable vomiting, and in one case in which no relief could be obtained by medical means, a laparotomy was performed, the stomach drawn out and then returned into the peritoneal cavity. The psychic effect or the mechanical stretching of the stomach itself resulted in cure.

Gastrotomy for the removal of foreign bodies in the stomach has been resorted to successfully during the past 25 years. The foreign bodies enter the stomach as a result of accident or are purposely swallowed as a livelihood, or on account of insanity. In preantiseptic days, Murphy

reports 19 cases of gastrotomy, with 15 recoveries and 4 deaths, or a mortality of 21%. In antiseptic days, 71 patients were operated upon, with a mortality of 9%. This includes early and late cases and at the present time if the cases are seen early the mortality is very low. Thus, modern surgery has developed to such a state of perfection that the stomach can be opened and foreign bodies removed with almost a certainty of success.

Gastrostomy is an operation employed for the relief of stricture of the esophagus, either benign or malignant, or for certain lesions connected with the stomach itself. It has for its prime object the prevention of death by starvation.

In 1883 Le Fort compiled some statistics in 105 cases of gastrostomy, in which he showed that the mortality from 100% was reduced to 74.2%. In 1885 Zisas collected 162 cases of gastrostomy, with 113, or 69.7% of mortality. In 1886 Knis had 169 cases of gastrostomy, with a mortality of 66.6%. In 1887 Heydenreich collected 33 new cases of gastrostomies, with 19 deaths, or 57% mortality. Since 1887 Guerin has collected 121 cases of gastrostomy, with 43 deaths, or 35.5% mortality. Mayo has performed gastrostomy with a much smaller death-rate than any mentioned. There can be no more beautiful illustration of the development of surgery than is demonstrated in this one operation, since formerly it was attended by a mortality of 100%, while to-day, after about a quarter of a century the operation has by evolution achieved a record that is most remarkable, since the latest figures show the mortality to be less than 30%.

Mikulicz recently performed 10 gastrostomies for the relief of non-malignant strictures of the esophagus, with only 7 deaths, or a mortality of about 20%.

Dennis operated upon a case of impermeable stricture

of the esophagus, caused by ulceration and cicatricial contraction by typhoid ulcers. This case is one of the two in which typhoid ulcers have been found. The patient is now living, seven years after the gastrostomy. His weight previous to the operation was less than 100 pounds, and to-day it is 184 pounds. He had not taken a mouthful of food except through the fistulous opening for several years and is perfectly well nourished.

Gastric ulcer has become a recent indication for operation. It has been performed 184 times as collected by Mayo Robson up to 1900. These 184 cases do not include those for perforation or hemorrhage; 157 patients recovered, and 31 died, thus giving a mortality of 16.4%. In 1901 statistics show that in 25% of cases of gastric ulcer the patients died under medical treatment, and only 5% under surgical treatment, according to the latest statistics. Gastric ulcer is a pathologic condition which formerly was considered exclusively from a medical point of view. To-day this disease in the stage of complication has been relegated to the domain of surgery. It has been during the past quarter of a century that progress has been made in the management of the serious complications, such as hemorrhage and perforation, of this intractable disease. Under medical treatment, the mortality of gastric ulcer in hemorrhage or perforation was nearly 100%, while under surgical treatment this frightful mortality has been reduced by the Mayos to 5% in the benign ulcers and 18% in the malignant ulcers. The advance that surgery has made in this disease has been in the study of the mechanics of the stomach, rather than the chemistry. Medical treatment based on chemistry was of little avail. Gastric ulcer of the stomach affords a striking illustration of the progress of surgery within the past decade. In addition to the reduction of the mortality from nearly

100% by medical treatment to about 5% by surgical treatment in the acute cases of hemorrhage and perforation, to 23% in the chronic cases with malignancy, there has been eliminated the danger of cancer engrafted upon an ulcer which at the beginning was benign.

Gastric hemorrhage is a condition which has been relieved through the mediation of modern surgery. These hemorrhages from the stomach are peculiar in that the smallest ulcers, which can scarcely be recognized by the naked eye on post-mortem appearances, have given rise to fatal hemorrhage. Mayo reports five cases of acute perforation and hemorrhage with three deaths.

Cancer of the stomach was a uniformly fatal disease. Under medical treatment no patient ever recovered. Surgery has entered this domain, and already the beneficent results are beginning to be felt. It must be remembered that this invariably fatal disease reaches, according to Haberlin, 40% of all the cases of cancer that invade the human body. Here is the most important and serious problem with which surgery has been confronted. Mayo assigns three reasons why surgery has never until recently interested itself in this fatal disease: (1) a belief that cure cannot be accomplished; (2) that the mortality of radical operations is almost prohibitory; (3) that the diagnosis cannot be made until the case is hopeless. In regard to the first reason, Mayo cites the fact that McDonald found 43 cases of cancer of the stomach, in which a permanent cure was effected by operation. Murphy collected 189 cases, in which the operation was performed by several operators, with 5% permanent cures in cases of over three years' standing. In some of these cures the patients were operated upon more than two years, and hence would, by law of average, survive to bring the percentage up to 8%. Beside these recoveries, Krönlein has proved by his statistics that human

life is prolonged 14 months over the unoperated cases. These facts are in striking contrast to the uniformly 100% mortality under medical treatment. The second reason why surgery has never generally entered the operative field for the relief of gastric cancer was due to the high mortality of 60% which Billroth published. This mortality has been happily reduced to 10% by improvement in technic and by early operation. If the operation is performed before adhesions have formed, and by men thoroughly trained in this field of operative work, the mortality will soon be even less than 10%. Mayo has had 41 cases of excision of the stomach, with a mortality of 17%. Out of the total number, 13 were performed by an improved method, with only 1 death, or 6%, while in the last 11 cases of excision of the stomach there was not a death, or the mortality zero. The mortality has been reduced in Mayo's last series of 11 cases to zero, from 60%, as reported by Billroth. No other statistics can be adduced to show so emphatically what surgery has achieved within a period of time that has elapsed since the erection of this magnificent building in this wonderful exposition. This one fact alone is the grandest and most striking proof of the miraculous work which surgery has accomplished, and to Mayo is due the credit of leading the world in this new department of surgery, which may be said to be the highest, the final, the most triumphant monument of the contribution of surgery to the human race. Here, again, is another striking illustration of what surgery has achieved. It has reduced the mortality of an operation in cancer of the stomach from 60% to 10%, and in a limited number to zero, and with every prospect in the near future of even a mortality of less than 10% in a large series of cases.

The third reason why surgery has not invaded this field lies in the fact that the diagnosis cannot be made by medical

means in time to effect a cure. Exploratory incision to find out is recommended by Mayo, and by this means an early operation can be performed that will be attended by small mortality as regards the operation itself, and a large percentage of cures as regards the disease itself. Cancer of the stomach, as a rule, is situated near the pylorus, just below the lesser curvature. Moynihan states that from this focus it spreads widely through the submucosa, and rapidly toward the cardia, and slowly toward the pylorus. Until very recently no surgery has been done upon the stomach for cancer, for the reason that it was considered a hopeless disease. Murphy collected 189 cases in which radical operation was done, with 26 deaths. Of these, 17 patients survived three years, or about 8% of cures. This is a gain in the right direction, since all patients die without operation. This 8% of cures was reduced to 5% by a return of the disease after three years. Mikulicz in 100 cases had an average duration of life of 15 months. The patients had relief from suffering at least 15 months, and there did not follow that terrible suffering so characteristic of the inoperable cases of cancer of the stomach. The reason that the results are not better in cancer of the stomach is owing to delay in operation, and when that obstacle is overcome the results will be brilliant, compared with the gravity of the disease. Time permits of adhesions, and when the operation is resorted to before adhesions form, the mortality is very much lessened. Thus Haberkaut had a mortality of 72% in cases with adhesions, and only 27% without adhesions. Gastrectomy was done, as reported by Murphy, in Kappeler's clinic, with 26% mortality, Krönlein with 28% mortality, Kocher 29%, Roux 33%, and Mikulicz 37% mortality. Murphy has called attention to the prophylactic treatment of cancer. He believes in the removal of conditions which seem to be es-

sential in the majority of cases to the development of the disease. Mikulicz has shown that 4% to 5% of the human race suffer from gastric ulcer, and that a fifth die as a result of the gastric ulcer. The other factor which largely influences the growth of cancer is the pyloric stenosis when the stomach cannot empty itself. The suggestion, therefore, is the removal of gastric ulcers by excision, and the relief of the pyloric obstruction by gastroenterostomy, and these prophylactic operations when performed early are attended with a comparatively small mortality, eliminates the possibility of cancer of the stomach arising from these two important and frequent causes.

Partial gastrectomy was twice performed by Langenbuch and published by him in 1894. In both cases seven-eighths of the stomach was removed. In 1898 Krönlein records all his own cases of partial excision of the stomach and Schlatter's case of complete excision. There were in all 24 cases, with 5 deaths, or a mortality of about 20%. Maydl, in 1899, reports 25 cases of cancer of the stomach, in which a partial gastrectomy was performed, with a mortality of 16%. Of the patients who recovered from the operation, 7 had recurrence very soon afterward, and the average duration of life was 11.7 months. In 1898 Kocher has reported 57 cases of resection of the pylorus, with 5 deaths, or a mortality of 8%. In the list there were 8 patients cured. Rydygier, in 1901, reported 25 partial gastrectomies, in which 8 patients recovered and 17 died, or a mortality of 68%. Czerny, in 1899, reports 29 partial gastrectomies, with 11 deaths, or a mortality of about 40%, and the average duration of life was 22 months. Morison reports 16 cases of partial gastrectomy, with 7 deaths, or a mortality of about 43%. Two of Morison's patients are still living. In one 6 years have elapsed, and in the other about 4 years. Mayo reports 48 cases of partial

gastrectomy for pyloric cancer, with a mortality of 12.5%, and in the last 19 cases there was only 1 death.

Complete gastrectomy was first performed by Conner, of Cincinnati, in 1883. The patient died upon the operating table. Complete gastrectomy was performed by Schlatter in 1897. The patient lived 13½ months. Complete gastrectomy was next performed by Brigham in 1898. The patient recovered from the operation. Complete gastrectomy has been performed 12 times, as reported by Robson and Moynihan. Four died as result of the operation, or a mortality of 33½. These cases are too recent for a pronounced opinion as to the permanency of the cure.

Surgery of the liver forms a unique chapter in the development of the science. Operations upon the gall-bladder and biliary ducts afford the most striking illustration of what modern surgery has achieved. Within the past 37 years this new operation has been performed with most gratifying results. It is a source of great national pride that this operation, destined to relieve so much intense suffering and to save life itself, was discovered in this country. To Bobbs of Indianapolis is due the great honor of the discovery of an operation which has accomplished these two beneficent results. In 1867, 37 years ago, Bobbs performed successfully the new operation of cholecystotomy and removed 50 gall-stones by an incision into the gall-bladder. This event marks an epoch in abdominal surgery that places this renowned Western surgeon upon a pedestal that commands homage and respect from the civilized world. Bobb's first cholecystotomy was soon followed, in 1868, by a second operation by another American surgeon, J. Marion Sims, who removed 60 gall-stones from the gall-bladder. To Tait, however, who was at the time of his death the greatest authority on hepatic surgery, belongs the great credit of perfecting the technic of this operation. Ex-

cision of biliary calculi by incision into the umbilical vein was performed by Dr. John C. Warren of Boston within the century. Such in brief is the history of the operation, the development of which from its crude to its almost perfect technic, forms a remarkable chapter in surgery.

Gall-stones with intestinal obstruction are attended under medical treatment, with a mortality of nearly 100%, while surgery has brought relief in a certain proportion of cases and with every encouraging prospect of a very great improvement. Courvoisier reports 125 cases, with a mortality of 44½; Schüller had 82 cases, with a mortality of 56%; Eve 28 cases, with a mortality of 40%; and Bannard 8 cases, with a mortality of 57%.

Cholecystotomy is an operation which consists in opening the gall-bladder for the relief of various conditions. Cholecystitis or inflammation of the gall-bladder is a disease that was formerly treated by medical means, with little or no prospect of cure if septic infection was present. In those cases in which gangrene or pus or rupture has occurred, medical treatment is attended by death; but surgical treatment may effect a cure in a large percentage of cases. Cholecystotomy is one of the most gratifying operations in surgery, because it relieves suffering, effects a permanent cure, and is attended by the exceedingly low mortality of less than 3%. The statistics of the operation of cholecystotomy varies greatly, owing to the special conditions for which the operation is performed. Mayo Robson states that when the operation is performed for simple disease, as gall-stones, when malignant disease and jaundice with infective cholangitis are absent, the mortality in 281 cases was only 1.06%. If now the complicated cases are included, such as phlegmonous cholecystitis, gangrene of gall-bladder, infective cholangitis with or without gall-stones, the mortality is only 2.7%. If further the malig-

nant cases be collected, in which cholecystotomy has been resorted to in the presence of cancer of the pancreas or bile-ducts, the mortality of the operation itself in 22 cases was only 5.8%. As regards the recurrences, the statistics will be mentioned later. Mayo reports, in 1902, 227 cases of cholecystotomy for various simple conditions, chiefly for gall-stones, with 6 deaths, or a mortality of 2.6%. The same operator reported, in 1903 352 cholecystotomies for simple conditions, with 8 deaths, or a mortality of 2.27%. For malignant disease the same surgeon reported, in 1902, 4 cholecystotomies, with 2 deaths, or 50% mortality, and in 1903, 5 additional cases, with 3 deaths, or 60% mortality. It is thus evident that cholecystotomy is attended by a high mortality when the operation is performed for cancer. It must be remembered, however, that the mortality is 100% under medical treatment. The mortality of 100% under medical treatment will never be improved, while the 50% or 60% mortality under surgical treatment will be reduced as diagnosis and technic improve, and early operation is performed. Kehr, in 1896, reported 209 cholecystotomies upon 174 patients. In the simple cholecystotomies, the mortality was only 1%. In the complicated cases the mortality was 58.8%. In a later series Kehr reported 202 cholecystotomies with 32 deaths, or a mortality of 16%. The higher mortality in this series is accounted for by the greater severity of the cases which earlier did not submit to operation. In conservative cholocystotomies Kehr had 68 operations with three deaths, or a mortality of 4.4%. In 1902 Kehr again reported his statistics, which consisted of 720 operations for gall-stones, with a mortality of 15%. In the simple cases of cholecystotomy the mortality was 2.1%, and in the complicated cases, including cancer, the mortality was 97%. Greig Smith reported 11 simple cholecystotomies with no mor-

tality, and one complicated case with death, or 12 cases in total, with a mortality of 8.33%. Lawson Tait reported 55 cases of cholecystotomy with three deaths, or a mortality of 5.4%.

Thus in cholecystotomy alone is an operation that has shown a steady improvement in its statistics. In no other operation is a greater contrast between the medical and surgical treatment of a disease at the present day.

Cholecystectomy is an operation which consists in excising the gall-bladder in a manner somewhat similar to the removal of the appendix. Ferrier reported, in 1901, 16 cases with 4 deaths, or a mortality of 25%. Courvoisier reported 47 cases with 12 deaths, or a mortality of 25%. Martig, in 1894, collected 87 cases of removal of the gall-stones with 15 deaths, or a mortality of 17.2%. Mayo Robson reports 28 cases with 4 deaths, or a mortality of 14.2%. Mayo, in 1902, had 31 cases with 3 deaths, or a mortality of 9.6%, and in 1903 had 70 cases with 3 deaths, or a mortality of 4.3%, and up to the present time he states that he has had 204 cases with a mortality of 4%. Kehr reported 21 cases with 1 death, and a mortality of 5%, and later another list with the mortality of 3%. Thus in cholecystectomy is another operation that has shown steady improvement in its statistics. This operation affords another illustration of the marked contrast between the medical and the surgical treatment, for in the former treatment no cure can be effected, while in the latter the percentage is very large.

Choledochotomy is an operation which consists of opening one of the biliary ducts and is a more formidable operation than opening the gall-bladder. Ferrier, in 1893, reported 20 cases, with a mortality of 25%. Kehr, in 1896, reported 84 cases, with 31 deaths, or a mortality of 37.8%. In a later series his mortality was reduced to 12.5%. Mayo states

that in 130 cases of benign series he had a mortality of 7.75%. Mayo Robson reported, in 1901, 37 cases, with 4 deaths, or a mortality of 10%, and since 1901 51 cases, with 1 death, or 1.9%, and later a consecutive series of 52 choledochotomies with no deaths. Choledochotomy is one of the most difficult operations in surgery, and the advance which surgery has made is shown by a reference to the great mortality of these cases for which this operation is performed, since under medical treatment suffering was not relieved and death often supervened, whereas under surgical treatment the mortality has been reduced even to 1.9%.

Cholecystenterotomy is a modern operation on the biliary passages, and consists in establishing a new communication between the gall-bladder and the intestine. Murphy reported 23 cases by use of sutures, with 8 deaths, or a mortality of 34%; 21 cases by Murphy's button, with no mortality, and 2 cases for malignant disease, with 2 deaths, or a mortality of 100%.

Cholecystduodenotomy has been performed by Murphys' button in 67 non-malignant cases with only 3 deaths, or a mortality of about 4%, and in 12 malignant cases by Murphy, 10 died, or a mortality of 83.3%. Mayo performed cholecystduodenotomy on 5 patients for chronic pancreatitis with no death, and 4 times for cancer with 1 death, or a mortality of 25%.

Pancreatic disease affords a field for the display of what modern surgery has achieved that astonishes the scientific world. Körte has computed the mortality of the operation for the cure of pancreatic cysts, and shows that Gussenbaur was the first to operate for the relief of this fatal disease. Previous to Gussenbaur's operation, the mortality under medical treatment was 100%. In the 84 cases collected by Körte, five patients died as the immediate result of the operation, thus giving the low mortality of not quite 0.6%

This statement seems incredible and affords the most startlingly unprecedented illustration which has no parallel in any other science. This operation has attracted great attention in the scientific world and its brilliant and unique record has been heralded throughout Christendom. Still more striking is another report of 15 cases of complete excision of the cyst of the pancreas with 13 recoveries, or a mortality of about 13%, and in 7 additional cases the extirpation has been only partial, since some of the cyst-wall was so adherent to important structures that its removal was impossible and 4 of the patients died, thus giving a mortality of 57%, which in contrast to 100% mortality under medical treatment is a great advance, though it is admitted that it is not what is expected, since as technic improves, the operation will be brought perhaps nearly as low as simple ovariotomy in the future. In evacuation and drainage of the pancreatic cyst there have been collected by Takaysan 17 cases with 1 death, a mortality of not quite 6%. Mayo had 5 consecutive cases of chronic pancreatitis with recovery in each case, and 4 cases of cancer of the pancreas with 1 death, or a mortality of 25%. Operations upon the pancreas afford another brilliant example of the achievements of surgery within the past few years. Mayo Robson and Moynihan, in 1902, reported 24 operations for the relief of chronic pancreatitis with 2 deaths and complete and perfect recovery in the 22 remaining cases. There is no more striking example of the progress which surgery has made than is afforded by this record. In cancer of the pancreas, which is always fatal, the operation has been attended by about 50% mortality, and in the other 50% the patients have survived a comparatively short period. This is an operation in which surgery in the future will have a better showing just as soon as the methods of diagnosis are improved so as to operate in the early stages of the disease. Mayo has had 37 cases of pancreatic disease with 2 deaths, or a mortality of about 5%.

Surgery of the spleen offers an illustration of the progress surgery has made during the past century. The cases of major operations upon the spleen are too few to make any extensive and reliable statistics. The prognosis which is most marked, and which interests us in connection with the subject of this address, shows improvement each year. Thus Murphy shows that in 1890, in the operated cases, the mortality was 70%. In 1897 the mortality was 37%. In 1899 the mortality was 26%. These figures are unsatisfactory, except to point out that in this new department of surgery great advance is made each year. Fevrier grouped under four heads the surgical conditions in the spleen that call for operative interference. They are traumatism, abscess, tumors, and displacements. As these conditions were nearly all fatal without surgical intervention, it is interesting to inquire what surgery has accomplished in this new field. Fevrier collected 56 cases of rupture of the spleen, in which splenectomy was performed 46 times, with 23 recoveries, thus giving a mortality of 50%. There were 8 cases of stab and gunshot wounds, with 3 deaths, or a mortality of 30%. Abscesses and hydatid cysts have called for operative interference, but there are no reliable statistics on the results. Malarial splenomegaly was operated upon 117 times, with 31 deaths, or a mortality of 26%. Displacements of the spleen have been operated upon by spenectomy and by splenopexy. Cases of extirpation of a movable spleen have been collected by Stierlin, who shows that the mortality is now only 6.25%. Splenectomy in echinococcus of the spleen, according to Bessel-Hagen, previous to 1890, was attended with a mortality of 60%, and from 1891 to 1900 the mortality was reduced to 10%.

Tuberculous peritonitis has been taken out of the realm of internal medicine and transferred to clinical surgery. It has now become an established routine of practice that

laparotomy is justifiable in cases of ascites in which the etiology does not depend upon disease of the liver, kidney, or heart. The method of invasion of the bacilli in their attack upon the peritoneum varies in different cases. The bacilli in rare instances may gain entrance through a perforation from a tuberculous intestinal ulcer, or from a purulent tuberculous vaginitis. Again, the peritoneum may become infected through a perforating tuberculous appendicitis, or from a tuberculous ovary, or fallopian tube. Williams, of the Johns Hopkins University, has shown that from 40% to 50% of the cases of tuberculous peritonitis can be traced to this origin. Abbe has demonstrated that about 66% of the cases of tuberculous peritonitis are due to infection of the thoracic lymph-nodes, and in only 16% is entrance gained by the mesenteric glands. It is thus evident that, while 16% of the cases of tuberculous peritonitis can be explained by infection through the alimentary canal from milk or other kinds of infected food, the great proportion is due to infection from the thoracic lymph-nodes. There is little doubt but tuberculous peritonitis may arise as a secondary affection following tuberculosis of the intestinal canal. Here again inhibition of infected milk and meats plays an important rôle. The entrance of tuberculous sputum into the stomach in those affected with pulmonary tuberculosis explains intestinal and peritoneal infection. The latter method of invasion is considered a frequent cause of peritoneal tuberculosis. The presence of tuberculous ulcers in the stomach in phthisical patients who subsequently suffered from intestinal tuberculosis has been thus explained by the investigation of Klebs. Many experiments upon lower animals which were fed with food containing tuberculous sputum and fragments of tuberculous lung have proved beyond doubt that intestinal and peritoneal tuberculosis can arise in this way. It is a strange clinical fact that laparo-

tomy for the cure of this disease has become established as a recognized procedure through errors of diagnosis. Sir Spencer Wells cured a case of tuberculous peritonitis by a laparotomy performed under the supposition that it was ovarian disease. Laparotomy, however, as a curative measure, was first introduced by Dr. Van de Warker, of Syracuse, N. Y. He blundered upon a case of tuberculosis of the peritoneum, under the supposition that he was operating for the cure of a case of hydrops of the peritoneum. Dr. Van de Warker presented this case at a meeting of the New York State Medical Association in 1883. From this time on, the operation of laparotomy for the cure of tuberculosis of the peritoneum has been practiced. The operation has, however, been modified from year to year; but most surgeons still adhere to the simple operation at first devised by our American surgeon. As regards the result of laparotomy for the cure of tuberculous peritonitis, surgeons differ largely in their statistics. Parker Syms shows that some claim 80% of cures, while others 24%. Marked improvement follows in 80% of the cases, and the mortality of the operation is only about 3%. Syms concludes that it is safe to estimate that 30% of the cases of tuberculous peritonitis are permanently cured by laparotomy.

In suppurative peritonitis surgery has opened up a new field within the past few years. The operation of incision into the peritoneal cavity has effected cures in a class of cases that heretofore were uniformly fatal. Murphy reports 7 recoveries out of 9 cases, or 77% of recoveries in diffuse suppurative peritonitis following appendicitis, while Dennis has had 11 cases of diffuse suppurative peritonitis without a death.

The radical cure of hernia presents one of the most forcible illustrations of the onward march of surgery. Coley reports 1003 operations with a mortality of less than a fifth

of 1%, and with relapses of less than a tenth of 1%. When it is considered that nearly one person in every 20, and even by some statisticians one to every eight, persons is born with a rupture, and these patients must wear trusses, the bane of human existence, and which are as necessary to the comfort and safety of the patient as a splint is to a fractured leg, the untold blessings of this one contribution of surgery to the human race become strikingly apparent. In other words, surgery offers to the thousands affected in this way a sure, perfect, and safe cure, and with the complete elimination of the uncomfortable, inconvenient, often painful, and sometimes dangerous instrument of barbaric times, the truss. What aseptic surgery has accomplished for the human family in the relief of this one distressing and common condition, no one can appreciate except he who has been the recipient of this blessing offered to him by the science of surgery. Until recently great expense was incurred and time consumed in fitting trusses. Many of these patients died as a result of strangulated hernia, which formerly had a mortality of over 50%. Now the possibility of strangulated hernia is eliminated and a radical cure effected with less than 1% mortality and 1% relapse. Perhaps one of the most forcible arguments to show the effect of certain improvements in the technic of surgical operations is demonstrated by the use of rubber gloves. In 116 cases of hernia operated upon at the Johns Hopkins Hospital prior to 1896, there were 28 cases of suppuration in the wounds, or 24%, while in 226 cases of the same operation with rubber gloves upon the surgeons' hands there were 4 cases of suppuration, or a fraction over 1%.

In umbilical hernia Mayo has devised an operation that offers relief to those patients who heretofore followed a life of constant suffering and danger. Mayo first performed his overlapping operation in 1895, and in a series of 50 cases

there was no mortality and no relapses except in which the relapse was only a partial stretching.

The operation for the relief of acute appendicitis is chiefly traced to the work of American surgeons. In 1843, Willard Parker, and later Gurdon Buck, did much to explain the nature of these iliac inflammations, and Sands cleared the way for the perfected operation of McBurney, which aims to prevent these dangerous peritoneal inflammations, and to prepare the wound for aseptic healing. Sands also first operated with success after perforation had taken place and general peritonitis was present. To McBurney is due great credit for the perfection of this operation, which is now recognized throughout the world as the best, safest, and most scientific way of managing these varieties of suppuration hitherto so fatal. The operation of removing the appendix vermiformis during the quiescent period between relapsing attacks was suggested by Sir Frederick Treves, of London, although the appendix was successfully removed in this country by Dennis in 1887. In this case the appendix was diseased, owing to adhesions to an ovarian tumor.

The surgery of the appendix is most interesting with a view to a study of what surgery of the past century has accomplished. There is probably no surgical disease about which so much has been written as appendicitis. The subject is trite and threadbare in many respects. There is little to be learned in regard to the etiology, symptomatology, and diagnosis of the disease. The operative technic can be but little improved upon in its present state of perfection. The mortality under proper antiseptic and aseptic conditions is so low that in the nature of the disease it will never in all probability be brought much lower. The percentage in these days of aseptic surgery in this abdominal operation is less than the percentage in the simple amputation of the

finger in the preantiseptic days. It would seem that surgery had reached its climax in regard to mortality in operation for the relief of appendicitis, yet the time will never come when there will be no death-rate. Complications are certain to arise that are beyond the control of the surgeon. Crural thrombosis, intestinal obstruction, acetonemia, embolism, shock of operation, intercurrent affections, all afford examples to show that some mortality must always exist. If a fraction of a per cent. can be gained in the reduction of the mortality, it is an advance in the right direction. The experience of surgeons during the past few years has demonstrated new methods, has pointed out new ways, and has discovered new facts, all of which tend to reduce the mortality. It seems now the only thing that is left to combine the various views of experienced surgeons into some uniform plan of treatment, in order to produce the best results. The mortality in appendicitis in all cases under medical treatment is about 16%, with 30% of relapses, while in diffuse suppurative peritonitis it is almost uniformly fatal.

The mortality in appendicitis in all cases under surgical treatment is about 4%, and with no relapses, and in diffuse suppurative peritonitis the mortality in published statistics is from 31%, the lowest, to 91%, the highest, and in my 11 consecutive cases of diffuse suppurative peritonitis the mortality was zero.

Ochsner has recently contributed some statistics from his own operations during one year, which reflect great credit upon his excellent work. In the acute there was a mortality of 3%, and in the chronic cases there was a mortality of 1%. In the entire number of cases, both acute and chronic, there was a mortality following the operation of 2%. Deaver has also recently contributed some statistics from his own operations extending over a period of one

year, which likewise reflect great credit upon his surgical skill. In the cases of general diffuse peritonitis there was a mortality of 31%. In the cases in which there was abscess there was a mortality of 12%. In the cases in which the disease was confined to the appendix, with stricture, ulceration, and necrosis of the mucous membrane, there was a mortality of 0.8%, and finally, in all the cases operated upon, the total mortality was 5%. Richardson's published statistics are practically the same, and the result of these various operators gives an idea of what surgery has accomplished. In a study of the last 119 cases of appendicitis occurring in my practice up to April 1, 1903, the mortality of the disease, irrespective of operation or of any special plan of treatment, was a little over 1.5%. In the cases treated without operation in which the attack was a mild, catarrhal one, and in which the patients were not operated upon during the attack, the mortality was zero. In this group of cases in which conservatism was employed for special reasons, the appendix was in many cases subsequently removed owing to repeated attacks, and the mortality was zero. In the group of cases in which the appendix was gangrenous and had ruptured into the peritoneal cavity with a general peritonitis, of which there were 11 cases, the mortality was zero. In the cases in which there was an acute perforative appendicitis, and in which the appendix was gangrenous, and found in a circumscribed abscess cavity, the mortality was 7%. If now, in this group, all the operative cases are collected, both acute and chronic, the death-rate was 2%. If the two fatal cases in the entire list of 119 cases are eliminated, which were hopeless from the start, but which were operated upon because it was offering the only possible chance of life, forlorn as the prospect was, the mortality of the disease was zero. The mortality of the operation both for acute and chronic appendicitis was also zero. Such cases as the two in which

death occurred will always happen, and will always prevent the absence of mortality in the disease. In other words, if the two fatal cases are eliminated on the ground that surgery is powerless to save when complications such as empyema and abscess of the lung exist, the mortality in the medical and operative treatment of this disease in 117 consecutive cases was zero. The two deaths which make the mortality of the operation in all cases about 2%, which in itself is insignificant when the nature of the disease is considered, deserve special consideration.

Richardson, of Boston, reports 574 appendectomies in the interval, with no deaths. Mayo has had 1668 cases in the interval, with two deaths, one from pneumonia secondary to an intercurrent attack of grip, and the other to surgical kidney following the use of catheter in an enlarged prostate.

Acute intestinal obstruction is a condition in former years almost universally fatal, while to-day surgery has afforded relief in this disease. Thus Wiggins gives a mortality of 67.2% for laparotomy. Excluding cases in which either the operation was abandoned, the bowel incised, and an artificial opening made, resection attempted, or an anastomosis effected, there are 45 cases, in which 24 resulted fatally, or a mortality of 53.4%. Counting only the operations that have been performed since 1889, and throwing out those cases in which the operation was not completed, we have a total of 18 cases, of which 14 were successful, and 4 unsuccessful, giving a mortality of only 32.2%. This Wiggin believes to be a fair estimate of the risk to-day of laparotomy performed in a young infant for the relief of this condition, if performed within the first 48 hours of the onset. This gives a chance of success represented by 78%, which according to this author, would speedily rise to 90%, as the patients come more frequently to operation during the first 24 hours.

Cancer of the bowel is a uniformly fatal disease. The recent advances in surgery have been the means of saving some of these patients. Mikulicz and Körte have each reported 12 cases of operations in which 9 of these cases had no return after four years, which is equal to 37% of permanent cures. Dennis operated upon a patient with cancer of the cecum, resecting six or seven inches of the bowel, and subsequently making an anastomosis with Murphy's button. The patient is now perfectly well after a lapse of many years since the operation.

Laparotomy was performed by Dr. Wilson, in 1831, for the relief of intussusception. The patient was a negro slave, and had suffered from intestinal obstruction for 17 days. The abdomen was opened, the intussusception was found, and it was drawn out and released, and the patient made a complete recovery.

In 1809 Physick was the first to ligate the éperon, when an artificial opening had been made in the intestine on account of pathologic changes. In 1847 Gross urged the excision of a section of the intestine, with suturing of the divided ends, with a view to establish the continuity of the canal, but the patient refused, and in 1863 Kinloch, of South Carolina, accomplished this result. In 1834 Luzenberg laid open a strangulated hernia, found it gangrenous, excised the mortified section of the intestine, stitched the serous surfaces, and the patient fully recovered. This same surgeon suggested, in 1832, exclusion of light to prevent pitting of small-pox. The operation of laparotomy for the treatment of penetrating gunshot and stab wounds of the peritoneal cavity was the work of American surgery. Gross, in 1843, and Sims, just before his death, both suggested this method, but these surgeons never practiced this method of treatment. It remained for Bull, of New York, to make the practical application of the method, and to him is due

DR. PEAN OPERATING BEFORE HIS CLASS.

Photogravure from the Painting by H. Gervex.

The fascinating gruesomeness of a serious surgical operation incorporated, so to speak, with the scientific aspect, is the subject of Gervex's ambitious effort, shown at the Paris Exposition, 1889. The operator is Dr. Jules Pean, author of several works on Surgery, Officer of the Legion and Member of the Institute, France. The painting represents a handsome young girl prepared to undergo an operation for an affection of the throat. Dr. Pean is explaining the case to his class before using the knife, and the countenances of his auditors indicate the gravity of his words, a treatment that evidences the genius of the artist.

the credit of this great advance in surgery. It is a source of national pride that laparotomy in penetrating wounds, and visceral injuries of the abdomen, was conceived, developed, and perfected in America. The widespreading influence of this operation is felt in abdominal surgery, and much of the present advance is the result of Bull's surgery.

Cancer of the rectum is a disease which was formerly uniformly fatal. Modern surgery has, however, rescued many of these unfortunate victims from a most distressing and painful death due to inanition, hemorrhage, and exhaustion. Taking the three-year limit as a point when it can be fairly stated that a return is rare after an operation, Krönlein collected 640 cases with a cure of 14% of over three years' lapse of time from the operation. Czerny, Bergmann, Kraske, and other surgeons report from 20% to 30% of permanent cures, and Kocher has had as high as 50% of permanent cures. The statistics of Kocher will be even improved upon as technic is perfected and early operation performed.

The first and only successful case of *laparotomy for the relief of perforation of the intestine* during the progress of typhoid fever was performed in this country, and to Dr. Weller Van Hook of Chicago is due the credit of having first established an operation for the relief of these cases, which hitherto were fatal.

Perforation in typhoid fever has given rise to an operation for the relief of fatal suppurative peritonitis. This operation is one of the most signal triumphs in modern surgery. In 1884 Leyden suggested and Mikulicz performed the operation. Haggard collected 295 cases in which operation was done up to May 1, 1903. Haggard states that 500,000 cases of typhoid fever occur in this country alone every year with a mortality of about 10% to 15%. Thus 50,000 to 75,000 patients perish annually from this

disease. Osler states that a third of the deaths in typhoid occur as a result of perforation and "Taylor thus estimates that 25,000 deaths occur yearly from this accident. On a basis of a possible 30% recovery by operative interference he further concludes that 7500 persons perish in the United States each year who might be saved." The mortality of perforation in typhoid is estimated by Murchison at 90% to 95%, and Osler says that "he could not recall a single patient in his experience that had recovered after perforation had occurred." Harte has shown that the mortality has steadily decreased as earlier operations were performed and technic improved; thus in 277 cases in successive intervals the mortality was as follows:

1884 to 1889,	10 cases;	mortality	....	90.0%
1890 to 1893,	16 "	"	....	87.5%
1894 to 1898,	110 "	"	....	74.5%
1899 to 1902,	141 "	"	....	66.6%

Duodenal ulcer has been operated upon with great success and is a signal illustration of what modern surgery has accomplished. Mayo operated upon 56 patients, in which 6 of the operations were for the relief of acute condition, with 3 deaths, or a mortality of 50%; and 50 operations for the relief of chronic condition, with 1 death, or a mortality of 2%. This operation marks an important epoch in the history of surgery. When the nature of the lesion is considered, the record is a most brilliant one. The difficulties of the diagnosis can only be appreciated when it is considered how similar are the symptoms of duodenal ulcer with pyloric ulcer, gastric ulcer, gall-stones, and other neighboring lesions. A few years ago there was no surgeon who was bold enough to attempt this life-saving operation. The uncertainty of the diagnosis and the frightful mortality that would have ensued made this operation for the relief of duodenal ulcer impossible.

Penetrating wounds of the abdomen are treated at the present time by an exploratory laparotomy, the value of which operation is evident by statistics reported by Postemski in 1891, in which he demonstrated that 60% to 70% of 645 cases of penetrating wounds of the abdomen terminated fatally, while the mortality was 100% when the abdominal viscera were injured. In a later series of penetrating abdominal wounds there were 36 uncomplicated cases, in which the patients were treated by exploratory laparotomies; all recovered, and 22 cases of penetrating wounds of the abdomen associated with intra-abdominal injury, in which 12 patients recovered.

Rupture of the intestine affords another striking illustration of the progress of surgery. Siegel has collected 532 cases in patients treated without operation and the mortality was 55.2%. In 376 cases in which operation was done, the mortality was 51%. This does not seem so great a triumph for surgery as might be expected, yet if these statistics are carefully gone over it becomes evident that the mortality is due to a cause which in the future can be obviated. Aggressive surgery can do much in these serious cases if operation is not postponed too late, as shown by Senn, and as for example:

Cases operated first	4 hours, mortality	15.2%
" "	5 to 8 hours, mortality	44.4%
" "	9 to 12 hours, mortality	63.6%
" "	later	70.7%

Rupture of the stomach has been cured by laparotomy; thus Petry found 44.5% of recoveries in 18 patients operated upon within 24 hours after the injury, and 25% of recoveries in 24 patients operated upon more than 24 hours after rupture.

Gangrene of the intestine forms an indication for resection of a segment of the intestine and offers a prospect

of recovery in a class of cases otherwise fatal. Thus Roswell Park resected 8 ft. 9 in. of bowel for the relief of a gangrenous condition and the patient recovered. The same surgeon assembled from surgical literature 16 additional cases in which over 200 cm. of bowel were resected with 14 recoveries, or 80% of cures, or a mortality of 17%. A singular fact recorded by Park is that when from 100 cm. to 200 cm. was removed, the mortality was 30%.

Subphrenic abscess is another serious condition which terminates, as a rule, fatally; but in which surgical intervention has been followed in a certain percentage of cases, thus Maydl records 74 operations with 39 recoveries, and 35 deaths, or a mortality of 47.2%.

Ovariotomy forms a new milestone in the march of surgery. In all probability the most important surgical event that has ever happened in this country and the world, was the conception, birth, and development of ovariotomy. To Dr. Ephraim McDowell of Danville, Ky., belongs this great honor. In 1809 he was the first one to perform this unique and original operation which has made his name immortal. The far-reaching influences that have proceeded from this step are incalculable. Dr. McDowell is to-day recognized as the originator of not only one of the greatest operations in surgery, but also as the author of an operation, the influence of which has made it possible to develop the present wide field of abdominal surgery. McDowell's work will live in the memory of thousands in this land, and will be honored the world over as long as time endures. In 1821 Dr. Nathan Smith performed ovariotomy in Connecticut, and without the knowledge that it had been performed by McDowell; Smith dropped the pedicle into the abdominal cavity and thus made a great advance in McDowell's operation. In 1823 Allan G. Smith also performed an ovariotomy in Kentucky, and David L. Rodgers

in New York in 1829. All these cases of ovariotomy were successful. It was seven years after this last American operation before ovariotomy was first performed in England, and nearly 15 years before ovariotomy was first performed in France. In 1870 T. Gaillard Thomas first devised and performed successfully a vaginal ovariotomy. In 1872 Dr. Davis, of Pennsylvania, performed successfully the same operation, followed in 1873 by Gilmore of Alabama, and in 1874 by Battey of Georgia, and later by Sims. In 1872 Battey performed his first oophorectomy, "with a view to establish at once the change of life for the effectual remedy of certain otherwise incurable maladies." This is an operation also of purely American origin, and has contributed much to the relief of human suffering. It has been urged that while to an American surgeon the credit is honestly due for the first performance of an ovariotomy, other nations have perfected the operation, and more credit is due to-day to other nations for the best results. Let us see how this statement accords with facts. In 1857 the question of ovariotomy was brought up for discussion at the French Academy of Medicine, and only one surgeon considered the operation as sometimes justifiable. Up to that time there had been in America 97 ovariotomies, with 34% mortality; in Great Britain, 123 operations, with 43% mortality; and in Germany, 47 operations, with 77% mortality. American surgeons, therefore, not only obtained the best results up to that date, but no American surgeon to-day will concede that our results are inferior to those obtained by surgeons in any other country at the present time. Few men can realize the influence of McDowell's first ovariotomy upon the whole field of abdominal surgery. It is, indeed, a sublime thought to consider that a man was found with the courage of his convictions to do what no man had ever done, and to operate

with the noise of an infuriated mob beneath his windows. This mob would have lynched him if the patient upon whom this first ovariotomy was performed had died. Having escaped the angry mob, he was pointed out as a murderer by his fellow colleagues, and was condemned by the highest scientific authorities in Europe. In America, therefore, under such circumstances and under such conditions, the birth of the greatest operation in surgery occurred—an operation which saves now the lives of millions of women. Keen asserts that "it is estimated that one million years are added every three years to the life of women in this country alone by a single operation of ovariotomy."

The disapproval of this great operation of McDowell's by the press, by the profession, and by the laity was pronounced. The *Medico-Chirurgical Review*, speaking of McDowell's achievement, says: "A back settlement of America, Kentucky, has beaten the Mother Country, nay, Europe itself, with all the boasted surgeons thereof, in the fearful and formidable operation of gastrotomy with extraction of diseased ovaries." All this vituperation was hurled at McDowell; but time, as the great arbiter, has demonstrated that what was said in sarcasm has become a transcendent and mighty truth. The noble character and the true grandeur of McDowell's nature, and his high and lofty ambitions, are illustrated by the fact that he had performed three successful ovariotomies, operations never before undertaken by man, without heralding the victories as triumphs of his personal ambition. In the early days of ovariotomy, McDowell, and Nathan Smith, the Atlees, Dunlap, Peaslee, Kimball, Sims, and Thomas established and brought to the front an operation against which the most bitter and scathing invectives were aimed. These great men, who have placed this operation upon a firm

basis, deserve the gratitude of a nation, and the world, since they have thrown a flood of light upon this dark region of surgery, which is now illuminated by the work of recent operators whose successes are simply miraculous.

Mayo Robson has contributed an article on the evolution of abdominal surgery, a part of which has reference to the results obtained in ovariotomy. He states that in Leeds Infirmary, in 1870-1871, no case was reported under abdominal surgery. In 1901, or 20 years later, there were performed in the Leeds Infirmary 569 abdominal sections. In reference to ovariotomy, he states that about 1870 ovarian tumors were considered a variety of dropsy, and tapping was resorted to as a means of transcient alleviation. Thus, in 1870, in St. Bartholomew's Hospital, London, there were only 3 ovariotomies performed, with 100% mortality. In Guy's Hospital, London, 5 ovariotomies, with 60% mortality. In St. Thomas's Hospital, London, 1 ovariotomy, with 100% mortality. In St. George's Hospital, London, 2 ovariotomies, with 100% mortality. In 1875, ovariotomy had such unfavorable statistics that tapping was done to defer a radical operation. In 1875, in 12 cases of ovarian tumor, only 7 patients had an ovariotomy performed, and 5 died, thus giving a mortality of 71%.

Now mark the contrast. In 1901, ovariotomy was performed 64 times, with 4 deaths, or a mortality of about 6%. When it is considered that in these cases some were malignant, gangrenous, and suppurating cases, the story seems incredible. Mouillin reports, in 1901, 57 ovariotomies in the hospital for women, with no death. Richardson, of Boston, reports 93 consecutive ovariotomies without a death. Ovariotomy in the aged shows most remarkable results; thus Kelly has reported in his book over 100 ovariotomies in women who were over 70, and operated upon by 59 surgeons, with only 12 deaths. This is a

triumph of surgery that Ephraim McDowell foreshadowed in his courageous work. Sutton collected, in 1896, 11 cases of ovariotomy in women over 80, with no deaths.

Ovariotomy during pregnancy has likewise a most astonishing record, since Williams in his book reports 142 cases collected by Orgler, with only a mortality of 2.77%.

In 1902, in one London hospital there were 40 ovariotomies, with 1 death, or 2.5% mortality, as contrasted with 100% mortality about 1870. Thus in a quarter of a century the mortality has been reduced in one of the most formidable operations in surgery from 71% to 6%, and in exceptional series of cases even to 2.5% mortality. It may be of interest to show the progress which surgery has made during the century in reference to the operation of ovariotomy, from 1809 to 1904.

In America—

McDowell	1809, and later,	12	cases;	mortality,	66%
N. Smith	1821,	1	"	"	0%
A. G. Smith	1823,	1	"	"	0%
Several operators	1855,	21	"	"	70%
In America	1857,	97	"	"	34%
In England	1857,	123	"	"	43%
In Germany	1857,	47	"	"	77%
Hofmeier	1903,	200	"	"	4.5%
Hofmeier	1903, last,	115	"	"	1.74%

From the above table it appears that during the first quarter of the nineteenth century, according to the combined reports of McDowell and N. and A. G. Smith, the mortality in 14 cases of ovariotomy was 57%. The combined English and American returns for 1855 and 1857 give an average mortality of 48%. The most recent figures are by Hofmeier, for 1903, who returns a mortality of 1.74%. If the earlier mortality prevailed at the present time, Hofmeier would have had 180 deaths in a total of 315 cases, instead of 11, which actually occurred.

Hysterectomy, or removal of the entire uterus, with or without the ovaries and tubes, affords a most striking illustration of the recent development of surgery. Hysterectomy shows brilliant results when performed for malignant disease; but the result of the operation when performed for malignant disease is the darkest chapter in the present status of surgery. Bigelow collected, in 1884 359 cases of hysterectomy for fibroids of the uterus, with a mortality of 58%. Kelly reports, in 1898, 100 cases of hysterectomy, including extirpation of the ovaries and tubes, with a mortality of only 4%. Pryor has investigated the subject of the mortality of abdominal hysterectomy for myofibroma of the uterus, and states that it is not over 2%, while in fibrocysts of the uterus, it is much higher, reaching at least 10%, and states that this great increase in mortality is due to "coexisting cardiac lesions, which so often accompany fibrocystic disease." Pryor also states that his mortality of hysterectomy in pus cases is about 3%. Noble reports 58 cases of pyosalpinx and abscess of the ovary, in which he performs hysterectomy with removal of the appendages, and the immediate mortality was not quite 2%, and 36 cases of removal of the appendages without hysterectomy, with a mortality of 5%. Richardson, of Boston, had a mortality of 3% in 111 cases during the past two years; and Polk, of New York, has had a long series of cases with equally brilliant results. Webster reports 65 hysterectomies for infective disease of the uterus and appendages, with a mortality of 1.07%. With such an array of statistics before us in hysterectomy, which may be considered the keystone of the arch, there is no more forcible illustration of the steady advance of surgery than the improvement in this operation. In regard to vaginal hysterectomy, statistics are likewise brilliant; thus Pryor has collected 228 cases of vaginal hysterectomy for non-malignant

disease, with one death. Webster reports 40 cases of vaginal hysterectomy for malignant disease of the uterus, with no death from the operation itself. No mention is made of the percentage of permanent cures in these cases.

Hysterectomy for the cure of cancer furnishes the most discouraging and melancholy statistics of any modern operation. In this case it is not so much the fault of the technic as it is the disease which calls for the operation. Cancer is most fatal in the uterus; but the time will soon come when early operations will effect a far greater percentage of recovery. Cancer of the cervix and body of the uterus is most fatal, yet the faintest glimmer of dawn is upon the horizon, and the results of hysterectomy for the permanent cure of cancer are beginning to show signs of improvement. In the history of every great operation the mortality is high at first; but as technic improves and early and radical operations are resorted to, the result will be different. Ovariotomy passed through just such a crisis, and it is certain that hysterectomy for cancer will show better results in the future and if so it will be the greatest triumph of surgery. The statistics of hysterectomy for cancer are subject to the widest variation. Penrose states that his results have been most discouraging, and he has only two or three patients who have permanently recovered. Penrose also criticises the report of 20% of cures for cancer of the uterus at the Johns Hopkins Hospital, and claims that "after due deduction and thorough sifting of their figures, 5% of cures comes nearer the actual truth." The mortality of the operation itself for the cure of cancer has a favorable showing in contrast to the results of permanent cure. Thus Pryor, in 1901, reports 98 cases of hysterectomy for cancer of the uterus with a primary mortality of about 11%. In a very careful and thorough research of the literature of the subject, I find that abdom-

inal hysterectomy for cancer has an immediate mortality of nearly 20%, if the cases from all available operators are taken, and that the immediate mortality for vaginal hysterectomy for cancer has been as high as 16%, and by some operators reduced to almost zero.

The Surgery of the Bones and Joints. The management of fractures has brought out the wonderful mechanical ingenuity which is a characteristic of the human mind. The application of the plaster-of-paris bandage in the treatment of fractures is one of the greatest improvements of the century. To the perfection of its technic, Fluhrer's work deserves special commendation. The use of flexible narrow strips of tin or zinc in the management of fractures was devised by Fluhrer in 1872, with the object of securing immobility of the fractured bones. The strips are not designed to act as rigid supports, although incidentally, by their width (a quarter of an inch) they edgewise oppose resistance to angular motion when passing through or near an axis of motion. Their principal effect is by virtue of their inextensibility, not shortening or lengthening under strain when bandaged to the limb in the principal planes of motion. They are roughened on each side by perforations, so that they may be securely held in position by the retaining bandage. They are not designed to serve as an accessory strengthening of an immovable splint; the strips themselves are the splint. The plaster-of-paris or other material incorporated in the retaining bandages gives to the provisional effect of the strips durability, which, of course, cannot be obtained by a simple bandage. The work of Dr. James L. Little, in the use of plaster-of-paris bandage, must not be overlooked, since he utilized this dressing for various fractures, and perfected several dressings for special fractures, notably the patella. Time will not permit of a discussion of the manifold ways that this

dressing can be employed in the different fractures. It will suffice to mention the present method of treatment of fractures of the thigh, in order to afford the best illustration of the evolution of the general plan of the treatment of fractures. If we start with Desault's splint, which was crude and unsatisfactory, the first change that occurred was Physick's modification, which consisted in making Desault's splint, which reached only to the crest of the ilium, extend above to the axilla and downward below the foot, with a perineal band for extension and counter-extension. In 1819 Daniell of Georgia introduced the weight and pulley. In 1851 Buck still further modified Physick's splint, so as to do away with the perineal band, and accomplished extension of the limb by the weight and pulley, after the manner of its present use. This was a great improvement, in order to overcome shortening of a fractured limb.

Van Ingen, in 1857, suggested the elevation of the foot of the bed to permit the body to act as a counter-extending force. The coaptation splints were used by Buck, in 1861, so that the present complete and perfect method is one that is the result of evolution, the consummation of which has been accomplished by the work of American surgeons. In 1827 Nathan R. Smith adopted the principle of suspension in the treatment of fractures, and the use of the sand-bag was introduced by Hunt, of Philadelphia, in 1862. In fracture of the clavicle, Sayre has originated a dressing which is not only unique, but which is accepted as the simplest, most reliable, and most satisfactory of all the different forms of apparatus. Physick suggested the two angular splints for treating fracture of the lower end of the humerus, and Gunning and Bean the interdental splint in the treatment of the fracture of the lower jaw. Allis first called attention to the pathologic

condition found in fractures of the lower end of the humerus, and suggested new principles in the treatment to prevent deformities. In 1861 Mason devised a new method of treating fractures of the nasal bones by passing a curved needle under the fragments and elevating them. In the treatment of fracture of the patella by the use of the metallic suture, American surgery can claim the operation as far as priority is concerned, since Rhea Barton wired a fractured patella in 1834, and McClellan, in 1838, and Cooper, of San Francisco, in 1861, and after him Logan and Gunn.

While American surgery cannot justly claim the priority of this operation as practiced by Lister with the modern aseptic technic, she can at least claim to having brought the operation to its present perfected technic, and can point to the fact that in New York the operation has been performed more times than it has been in any city, or in any country in the world. While the operation is not one to be recommended universally, it is an operation yielding brilliant results in suitable cases and in the hands of aseptic surgeons. The first time that fractures of the lower jaw were treated by metallic suture was by Kinloch of South Carolina. In the management of ununited fractures, American surgery stands preëminent. In 1802 Physick passed a seton between the ends of an ununited fracture of the humerus. In 1830, or twenty-eight years after the operation, Physick obtained the specimen. The use of the metallic suture was first successfully tried in 1827, by J. Kearney Rodgers, in a case of ununited fracture of the humerus.

Perforation of the ends of the bones in an ununited fracture of the tibia was accomplished in 1850 by Detmold. In 1825 Brainard introduced the operation of drilling the fragments. In 1857 Pancoast used the iron screw to ac-

complish the same object. In 1878 Pilcher first pointed out the correct pathology and the treatment of fractures of the lower end of the radius. Before dismissing the subject of fractures, the work of Hamilton and Stimson must not be overlooked, since they did more to systematize and to perfect the treatment of fractures in general than any other surgeons. The saw devised by Shrady for performing a subcutaneous section of the bone is an instrument worthy of the highest commendation. Excision of the superior maxillary bone, with the exception of the orbital plate, was first performed by Jameson, in 1820. The complete excision of the superior maxilla was first performed in New York, by David L. Rodgers, in 1824. Excision of the inferior maxilla was first partially and successfully made "without known precedent or professional counsel or aid," by Deadrich, of Tennessee, in 1810. Jameson exsected nearly the entire inferior maxilla in 1820. Mott exsected half of the jaw in 1821; Ackley in 1850; and Carnochan excised the entire bone in 1851. Excision of the os hyoides was performed for the first time by Warren, in 1803. Excision of the wedge-shaped piece of bone from the tibia and fibula, with osteoclasis of the bones, to correct a deformity by an osteotomy, was performed by Warren, in 1820. In 1835 Barton devised an operation which is still practiced for the relief of angular ankylosis of the knee. The entire clavicle was excised successfully for necrosis for the first time in 1813, by McCreary of Kentucky. The entire clavicle was again excised successfully for the first time for malignant disease, by Mott, in 1828. The entire scapula, three-fourths of the clavicle, and the arm were excised for the first time, and also successfully, by Dixi Crosby, in 1836. This same operation was repeated by Twitchell, in 1838, by McClellan, in 1838, and by Mussey, in 1845, and since then to the present time the

operation has been performed many times throughout the world.

The entire scapula and the clavicle were removed successfully six years after an amputation at the shoulder-joint by Mussey in 1837. Two-thirds of the ulna was excised successfully by Butt, of Virginia, in 1825, and the olecranon by Buck, in 1842, while the entire ulna was excised by Carnochan, in 1853. The same operator excised the entire radius in 1854. Both radius and ulna were excised by Compton, of New Orleans, in 1853. Excision of the coccyx was first performed by Nott, in 1832, for the relief of severe and persistent neuralgia. Excision of a portion of the rib by the trephine, for affording drainage in empyema, was first performed by Stone, in 1862, and excision of a part of one or more ribs for the same purpose was first performed by Walter, of Pittsburg, in 1857. Beside these excisions for necrosis, suppuration, and malignant disease, much credit is due to American surgery for the part it has played in subperiosteal surgery. One of the most remarkable specimens is the reproduction of the inferior maxilla by Wood, in 1856. Langenbeck, the authority on subperiosteal surgery, said "that he did not believe a corresponding preparation really existed anywhere," and remarked that "there was not another such specimen in the whole of Europe." This was indeed a fitting tribute, from one of Europe's greatest surgeons, to the genius of one of America's greatest operators. Wood has also succeeded in reproducing many other bones in the body by the application of the same principles of subperiosteal surgery. Thus it is evident, if the first successful excision of the superior and inferior maxillas, the hyoid, the entire clavicle, the entire scapula, the ulna and radius, the coccyx and ribs; also trephining for relief of osteomyelitis; the most perfect specimens of reproduced bone,—be subtracted from the sum

total of operative surgery upon the bones, there is little left that is not the offspring of American surgery.

In the surgery of the joints, American surgeons have accomplished brilliant work, since in the management of dislocations they have contributed much to the sum total of our knowledge. Physick was the first to perform venesection to cause muscular relaxation, in order to reduce a dislocation. This was a most valuable means, to which resort was made prior to the introduction of anesthetics. McKenzie and Smith, in 1805, reduced a dislocation of the shoulder of six months' standing by the employment of venesection. This patient had been to England and all attempts at reduction failed, and upon his return to Baltimore, the reduction was effected by relaxing the muscular system by blood-letting *ad delequium animi*. The plan is now abandoned since the introduction of anesthetics. Warren excised the head of the humerus to restore the usefulness of it after an unreduced dislocation of the shoulder-joint. The invention of plaster-of-paris jacket by Sayre, for the treatment of Pott's disease, in 1874, is one of the most important surgical discoveries of the century. The same apparatus he devised for the treatment of lateral curvature. These cases of Pott's disease, which hitherto were consigned to a distressing death, are now permanently relieved of their sufferings, and are in many cases entirely cured. Excision of the hip-joint was performed as a systematic operation, and successfully, for the first time in this country, by Sayre, in 1854. To this same surgeon is due the credit of suggesting and carrying into execution the principle of free drainage in cases of empyema of joints. In hydrops articuli, Martin, of Boston, in 1853, suggested equable uniform compression by means of an elastic bandage, and Sayre has applied the same principle by using compressed sponges. Martin, in 1877, also employed the

elastic bandage for the cure of chronic ulcers of the leg. In 1826 Barton divided with a saw the great trochanter and the neck of the thigh to relieve ankylosis of the hip-joint. In 1830 Rodgers removed a disk of bone, and in 1862 Sayre perfected the operation and introduced a new principle by removing a plano-convex wedge of bone between the two trochanters, and made rotund the end of the lower fragment in order to form a new and artificial joint. In 1835 Barton removed a cuneiform wedge just above the condyle and fractured the bone, and made the limb straight to relieve angular ankylosis of the knee-joint. This operation is practically the osteotomy of the present time. In 1840 Carnochan first operated for the relief of ankylosis of the lower jaw by subcutaneously dividing the masseter muscle. In forcing open the mouth after tenotomy of the muscle, he accidentally fractured the bone, thus producing a false joint until the fracture united. Carnochan conceived then the idea of excising a wedge-shaped piece from the jaw and establishing a false joint. For the relief of this distressing condition, in 1873, Gross excised the condyle and a portion of the neck of the bone, and in 1875 Mears excised the coronoid and condyloid process together with the upper half of the ramus. Wood, in 1876, cured a patient with fracture of the cervical vertebra associated with paraplegia and brachial paralysis, by the use of the plaster-of-paris jacket. The patient, though completely paralyzed, made an excellent recovery and was able to resume his work as a carpenter.

Compound fracture may be designated as the touchstone of surgery, because a discussion of the treatment of compound fractures includes all the great principles involved in every department of the science. It embraces a consideration of cerebral, thoracic, and abdominal surgery; it includes a discussion of the great principles of antisepsis,

it covers operative technic, it embraces the study of surgical pathology, it touches upon the higher departments of the science, and opens up the field where surgery must be considered, as an arena for the exercise of sound judgment, for the display of clear foresight, and for the exhibition of accurate knowledge and ripe erudition. Finally, a full discussion of this subject inevitably leads to a consideration of the progress of surgery during the present century and its precise status at the present day. In considering the management of compound fractures, I shall confine myself to the results of my own personal work as embodied in an extensive clinical experience embracing a report of 1000 cases, which I published some time ago, and since then hundreds more can be added to my list, with substantially the same result. These cases occurred within a period of a year in four metropolitan hospitals devoted to the treatment of acute surgical cases, and also in private practice. The accumulation of so vast an amount of clinical material has been attained with considerable labor. The conscientious treatment of these serious cases has been attended with a sense of great responsibility, and the results have been attained only by close attention to the minutest details in the management of each individual case. There are some points in the treatment of compound fractures that deserve special consideration, and it is only by a study of these cases in groups that clinical facts of essential importance can be established. The same plan of treatment has been carefully watched in many cases at the same time, and it has been by a process of evolution that some of the opinions which I shall enunciate have become fixed laws in routine practice. To see in one day nineteen compound fractures in the same ward with a normal temperature is not a coincidence. The number might possibly be, but the same condition in all is the re-

sult of the application of fixed principles which have been established as the result of long study and observation. To see at another time twelve cases in the same ward and all with a normal temperature is likewise no coincidence. These circumstances make it evident that the application of fixed rules is necessary to arrive at certain and uniform results.

The complete history of each one of the 1000 cases of compound fracture is carefully preserved. Each case is given in full, with the name of the patient, the date of his or her admittance to the hospital, the age, a description of the injury, the treatment in full, and the result, together with the name of the house surgeon on duty at the time as a matter of reference. It is obvious that time will not permit to discuss in detail these histories, and therefore I can only give a summary.

The general summary in the 1000 cases is as follows:

Skull	178
Nasal, malar, maxillas, and patellas	89
Arm	40
Forearm	41
Fingers and Toes	97
Ilium, clavicle	2
Thigh	87
Leg	295
Fractures involving shoulder, elbow, or wrist-joints, as a result of disease or accident	39
Fractures involving hip, knee, or ankle-joints, as a result of disease or accident	85
Fractures involving carpal or metacarpal, tarsal or metatarsal joints, as a result of disease or accident	47
	1000

Now, following the example of surgical writers who have carefully tabulated the results of treatment in compound fractures, I shall eliminate all those cases in which primary amputations were performed, because they do not concern

the point at issue; and I shall also, according to the practice of writers, reject all those patients who died of hemorrhage, collapse, shock, etc., within a few hours after injury. I shall also leave out cases of compound fractures of the hand and foot, as too insignificant to be classed with compound fractures of the long bones. After these deductions are made, there remain 681 cases of compound fractures, with one death due to sepsis. This gives a death-rate of about $^1/_7$ of 1%.

In order to appreciate fully what aseptic surgery has accomplished in reference to the management of compound fractures, it is necessary to compare the results obtained prior to the introduction of antiseptic surgery. In the Pennsylvania Hospital, Norris has made a statistical report of the compound fractures treated between the years 1839 and 1851. During that time there were 116 cases of compound fractures of the leg and thigh (excluding those cases requiring amputation) with 51 deaths, thus giving a rate-mortality of 44%. In the New York Hospital during the same period there were treated 126 cases of compound fracture of the leg and thigh (excluding those cases requiring amputation) with 61 deaths, thus giving a rate of mortality of 40%. In the Obuchow Hospital reports of St. Petersburg there are 106 cases of compound fracture with a mortality of 68%. In Guy's Hospital, from 1841 to 1861, there were reported 208 cases of compound fractures with 56 deaths, giving a mortality of about 28%. Billroth reports from surgical clinics of Vienna and Zurich 180 cases of compound fractures (excluding cases of amputation), with a mortality of 31% from septopyemia. Now, after the introduction of antiseptics, a study of Billroth's table of compound fractures shows a reduction in the death-rate to about 3%. The influence, therefore, of antiseptics has caused the death-rate

to fall from 68% to about 3%. In my personal report of 1000 cases, the fractures of the extremities only are compared, as has been done in all of the above tables; there is no death from septopyemia, and thus the rate of mortality from blood-poisoning is now reduced from 68% to zero. It may be said, therefore, that pyemia and septicemia, which formerly destroyed as many as 68% of compound fractures, have been practically eliminated.

The science of surgery has at last demonstrated to the world that it has fairly met these demons of destruction, and that it has conquered them. Without doubt the means of warfare have been found in the establishment of bacteriologic laboratories, for without these institutions the discoveries that affect the happiness and mortality of the human race could not have been made. For my own part, I remained a skeptic to the germ-theory of inflammation until the Carnegie Laboratory afforded me an opportunity to work out this great problem. The reduction of the death-rate from 68%, which half a century ago was considered a brilliant achievement, and a result which was thought worthy of publication, to that of a cipher, represents what surgery has done for the amelioration of human suffering and the preservation of life. These statistics afford us the most startling and impressive lesson of what surgery has done. It has lessened suffering, it has annihilated pain, it has saved limbs, it has conquered sepsis, it has saved life. Surely nothing could be added to show more clearly the triumphant march of the onward progress of the grandest profession in the world.

Compound fractures of the skull require surgical interference which formerly was not resorted to unless in extreme cases. The intervention of operative measures has not only reduced the mortality to a very small percentage by preventing an infective process, but it also has elimi-

nated the various nervous phenomena, such as headache, ataxia, epilepsy, insanity, and other like conditions. I have treated many hundred cases of compound fractures of the skull, and at one time collected a series of 116 cases of my own, a reference to which may give an idea of what modern surgery has achieved in the past few years in the management of this class of serious cases. Of these 116 cases of compound fractures of the skull, excluding those deaths from shock within 48 hours, in accordance with all statisticians, because these deaths were not the result of any special plan of treatment, there are two deaths which may be ascribed to sepsis. Perfection has been almost reached in the technic of the operation of trephining; but as yet there are circumstances which are not controlled by the practical surgeon, and in the study of these causes future scientific surgery must be employed. In these 116 cases of compound fractures of the skull, there were two deaths due to sepsis, which give a mortality of less than 5%.

Traumatism of the vertebral column and the spinal cord have been treated by Sayre's plaster-of-paris jacket. The utter helplessness, the intense suffering, the absolute hopelessness, the wretched discomfort, the living death make these patients objects of pity to all under whose care they come. On the other hand, the recent advances in the science of neurology, the precision of topographic anatomy, the modern researches in physiology, the introduction of anesthetics and antiseptics, the wonderful inventions in mechanical art present a most vivid picture to the modern surgeon of what surgery has accomplished by this new method of treatment. The expectant plan terminates in death, the application of well-recognized surgical principle to this peculiar class of hitherto neglected cases, has demonstrated the possibility of salvation in at least a limited number. The treatment of all these different varieties of

traumatism of the spine and cord by the plaster-of-paris jacket has met with brilliant results. Before the employment of the jacket, these patients were doomed to unalleviated suffering and death. There is no reason why the same brilliant results should not follow the application of the jacket when used in connection with spinal meningitis or myelitis secondary to traumatism. Some time ago I collected thirty-three cases of recovery after unmistakable fracture of the spine, and to this list many others can be added of recent date. Cases have been eliminated in which improvement only was noted. This list is sufficiently large to attract the attention of surgeons and to induce them to employ this method of treatment in all forms of traumatism of the spine and cord. Still again, the usefulness of the jacket is demonstrated in a large list of injuries, among which may be mentioned sprains, concussion, hemorrhage, lacerations, and inflammatory thickenings. Thus it is evident that immediate extension and counter-extension with immobilization by means of the jacket, in all forms of spinal injuries, offers the most satisfactory plan of treatment that has been suggested, a plan of treatment, too, in which the results show manifest evidence of improvement, and further a plan of treatment that has been attended with a most gratifying success.

Orthopedic surgery is a department by itself, a part of which will be discussed under pediatrics. Under orthopedic surgery there are, however, a few operations that could be referred to briefly in order not to overlook the importance of the subject. Orthopedic surgery literally refers to the treatment of deformities; but the progress in this department has already passed beyond the limits that originally were set for it, and include now some of the operations in general surgery. Among the advances mentioned by Taylor are the Lorenz bloodless method of

manual replacement of congenitally dislocated hips, the correction of deformed limbs by forcible movement without division of the tendons, the straightening of the kyphotic spine by great force, as suggested by Calot, the use of Sayre's plaster-of-paris jacket for correction of Pott's disease, the straightening of deformities in the limbs of osteotomy, the correction of deformities affecting the long bones by osteoclasis, the arrest of disease of the joints by excision, the removal of osteomyelitic foci in bone by excision or by the Röntgen rays, tendon grafting suggested by Dr. Vulpius, nerve suture for transference of functional activity from a healthy nerve to a paralyzed nerve, the tuberculin injection from diagnostic purposes, the extirpation of articular disease, the cure of periarticular bursitis and tenosynovitis, the healing of non-tuberculous joint disease where the etiology is dependent upon microörganisms such as are found in typhoid, pneumonia, gonorrhea, syphilis, and septic infection; the management of atrophic and hypertrophic joint disease by improvement in the physical condition and correction by mechanical means, and finally the treatment of Paget's disease of the joints, or osteitis deformans.

Surgery of the Vascular System. In the surgery of the vascular system American operators have made most valuable contributions. The innominate artery was ligated for the first time in the history of surgery by Valentine Mott, of this city, on May 11, 1818. The operation was performed for the cure of aneurism, and the patient died. The operation was essayed for the second time by Hall, of Baltimore, in 1830, and again by Cooper, of San Francisco, in 1859. Both of these cases terminated fatally. The artery was finally tied successfully for the first time by Smyth, of New Orleans, on May 9, 1864. This last operator tied also the vertebral in the same patient for the

first time. Thus it is evident that the ligature of the innominate artery was first performed in this country, and it was first ligated successfully in America. Mott tied 138 large arteries for the relief of aneurism, and no surgeon in the world ever has ligated so many vessels. The primitive carotid artery was ligated for the first time successfully, for primary hemorrhage, by Cogswell, of Hartford, on November 4, 1803. Abernethy is accredited with tying the primitive carotid first in 1798, but his patient died. The first successful case, therefore, of ligature of the primitive carotid for primary hemorrhage was in America, and Cogswell had no knowledge of Abernethy's unsuccessful attempt. Again the primitive carotid was first tied successfully for secondary hemorrhage by Amos Twitchell, of Keene, N. H., in 1807, eight months prior to Sir Astley Cooper's famous case, which was supposed until lately to be the first on record. The primitive carotid was first tied in its continuity successfully, for the cure of aneurism, by J. Wright Post, on January 9, 1813. This same surgeon repeated the operation successfully on November 28, 1816. The two primitive carotids were first tied in their continuity successfully, within a month's interval, by Macgill, of Maryland, in 1823. Mott tied both carotids simultaneously in 1833, for malignant disease of the parotid gland. In 1823 Davidge first tied the carotid artery for fungus tumor of the antrum. The primitive and internal carotids were first tied simultaneously by Gordon Buck, of New York City, in 1857, and again by Briggs, of Nashville, in 1871. The internal carotid was tied successfully above and below, for secondary hemorrhage, by Sands, in 1874. Carnochan tied both carotids for the first time for elephantiasis arabum of the neck and face, in 1867. The subclavian artery in its third portion was first tied successfully, for the cure of aneurism, by J. Wright Post, of New

York City, in September, 1817. The subclavian artery in its first portion was ligated for the first time by J. Kearney Rodgers in 1845. The patient died and the vessel has never been tied successfully until 1892, when it was tied by Halsted, of Baltimore. The operation was for the cure of aneurism, and the sac was dissected out by removal of the clavicle.

This is the only case in which ligation of the subclavian on its tracheal side has ever been successful, although it has been attempted in other countries; but the vessel has never been tied successfully, except in this country. The primitive iliac artery was first tied in America by Gibson, of Baltimore, in 1812. The ligation was for the arrest of hemorrhage following a gunshot wound. The patient died on the thirteenth day. Valentine Mott tied the artery successfully for the cure of aneurism, on March 15, 1827. In 1880 Sands first tied the primitive iliac, by performing first a laparotomy and securing the vessel by this procedure. The internal iliac was first successfully tied for the cure of an aneurism by Stevens, in 1812, and again successfully by Mott, in 1827, and by White, in 1847. The two internal iliacs were first tied simultaneously for the cure of double gluteal aneurism by Dennis, in 1886, upon a patient belonging to Dr. Carpenter, of Boonton. In this case a laparotomy was performed as a preliminary step. The same operator has since tied successfully the internal iliac for the cure of gluteal aneurism, for the first time, by laparotomy, as a preliminary step to operation. The external iliac was tied successfully in 1811, by Dorsey, and again successfully by Post, in 1814. Onderdonk, in 1813, tied the femoral artery successfully for acute phlegmonous inflammation of the knee-joint, and Rodger did the same operation with success in 1824. Carnochan, in the year of 1851, tied the femoral artery for the first time for the

cure of elephantiasis arabum, thereby inaugurating a new principle of treatment. In addition to the various ligations already mentioned for the cure of aneurism, the invention of a variety of compression, known as digital pressure, was carried into practice by Jonathan Knight, of New Haven, in 1848.

There are many modifications of digital pressure. Wood utilized the bag of shot which was suspended above the patient, and by this means the pressure was effected by it instead of by the finger. In 1874 Stone of New Orleans first cured a traumatic aneurism of the second portion of the subclavian artery by digital pressure upon the third portion of the vessel. Martin, in 1877, suggested the use of the elastic bandage in the treatment of varicose veins, and recently Phelps, the method of the multiple ligature of the veins from the ankle to the saphenous opening. He applies some 60 ligatures to the limb, and the results of his operations have been most satisfactory.

There has been much diversity of opinion as to whom the credit belongs for the introduction of the Esmarch bandage. In the public clinics of the Jefferson Medical College, at the time of an amputation, the limb was rendered bloodless by elevation of it, and by the application of a roller bandage to it by the elder Pancoast and Gross. This was done before a tourniquet was applied. The value of this procedure was not published, and to Esmarch is due the credit of having adopted the principle with the modification of the elastic bandage, and having published it abroad for the benefit of the profession.

In the surgery of the nerves the work performed by Americans is most commendable. In 1856 Carnochan excised the second branch of the fifth cranial nerve beyond Meckel's ganglion for the relief of tic douloureux, and two years later Pancoast performed the same operation

in the pterygomaxillary fossa. The mortality of the Kraus-Hartley operation for the relief of tic douloureux by removal of the gasserian ganglion in 108 cases collected by Tiffany was 22.2%. In a later series collected by Murphy the mortality of the operation was reduced to 16%. The recurrence of pain after the operation is observed in about 10% of the cases. This operation is one of the most beneficent ones in surgery, as it has afforded relief from the most excruciating pain and suffering.

In 1863 Gross removed the inferior maxillary branch of the same nerve. In 1871 Sands excised a piece of the brachial plexus for the relief of persistent neuralgia of a traumatic origin. Gross for the first time excised nearly two inches of the spinal accessory nerve. The sutures of nerves, even three days after division, have been united with restoration of the function of the nerve. Operation for the relief of facial paralysis marks a new epoch in surgery of the nerves. There have been 12 cases of facial paralysis reported by Faure. In these cases the paralyzed facial nerve was exposed by dissection and then united to the hypoglossal or the eleventh nerve, and through this inosculation, motor stimulus was given to the facial, which had lost its function. The results have been most satisfactory, even though the face had been paralyzed from five months to three years.

Amputation shows a steady improvement in its results during the past century. In this department of surgery American surgeons have not only taken the initiative in the more important amputations but they have perfected methods devised by eminent surgeons in other countries throughout the entire world. The first successful primary amputation at the hip-joint was performed by a Kentucky surgeon named Brashear, in 1806. The amputation was repeated with success by Mott, in 1824. Nathan Smith was

among the first, if not the first, to successfully and systematically amputate at the knee-joint, in 1824, and the technic of this operation has been perfected by Markoe and Stephen Smith. The first successful amputation of the ankle-joint in any country was performed in 1842, by Syme, in Scotland. Triple simultaneous amputations have been performed successfully, also quadruple amputation. These are among the curiosities of surgery, and illustrate the preservation of human life in the face of the greatest danger.

In the invention of prothetic apparatus the ingenuity of the American mind has discovered a most wonderful field of operation, since in no country can be found the mechanism that is displayed in the manufacture of aluminum artificial limbs. I have at present patients who can walk and even run with two artificial limbs, and one who has artificial hands who is employed as a pharmacist.

Staphylorrhaphy was performed by Warren, in 1820, the same year, it is just to state, that the operation was performed in France by Roux, but Warren had no knowledge of Roux's method.

Excision of the tonsil was an operation placed upon a permanent and safe basis by Dr. Cox, of New York. This surgeon invented, in 1820, an instrument which included the tonsil in a ring, and then cut it by a ring-shaped knife. The guillotine principle applied to the tonsillotome was an improvement upon this instrument.

The operation for the relief of goiter is a great advance in operative work, since this was formerly one of the most serious operations in surgery. Wölfer reports 60 cases collected from Billroth, Socin, and his own clinics with only two deaths. Reverdin's mortality was only 2.8%, Kocher's results are most brilliant, 0.2%. Mikulicz's 2.6%. The treatment of cretinism and myxedema by

thyroid extract is another method of cure that has been followed by recent success in a fair percentage of cases, though the use of the drug must be continued for at least two years.

The operation for rhinoplasty to restore a lost nose is one of the triumphs of the century, and plastic operations for the restoration of a partially destroyed nose is also a contribution of modern surgery. *Cheiloplasty,* or the formation of a new lip, is another plastic operation, the product of aseptic surgery. *Stomatoplasty,* or the repair of defects of the lips from contraction due to burns, and *metoplasty,* or the repair of defects of the cheeks and *blepharoplasty* the repair of defects of the eyelids, are illustrations of the beneficent work that surgery has achieved.

Surgery of the Genito-urinary System. In the department of genito-urinary surgery a great advance has been made by the invention of instruments to facilitate and improve the technic.

The cystocope is an American instrument, having been invented by Fisher, of Boston, in 1824, Civiale and Heurteloup having invented their instruments in 1827. The cystoscope of to-day is one which has been evolved from the general principle of Fisher's endoscope. Otis has perfected the urethroscope by the addition of a new lamp for the electro-urethroscope. Klotz has also devised a cystoscope which is in use at the present time. Brown has devised a most useful urethral speculum for the purpose of making topical application to the canal. The Gross urethrotome, also Powell's urethral dilator, and the Otis dilating urethrotome, and the urethrotometer are instruments deserving of worthy mention. The work of Bumstead and of Van Buren in this department of surgery have already world-wide reputation. The operation of nephrectomy for the relief of malignant disease of the kidney is of American

origin, since it was first performed by Wolcott, of Milwaukee, in 1860. British surgeons give the credit of this operation to Simon of Heidelberg; but he did not perform his operation until 1869, or nine years after Wolcott's operation.

Nephrectomy was first performed in America for gunshot wound of the kidney by Keen in 1887, and again two months later for the same reason by Willard, and still again for the same cause by Price, successfully, in 1888. The first successful operation for the relief of extroversion of the bladder was performed in New York by Carroll on April 13, 1858. Pancoast performed the same operation successfully the same year, and Ayres in 1859. All of these cases antedate the British successes of Woods and Holmes, although there are two operative failures reported by Crook and Lloyd in London in 1851. In plastic surgery of the urethra another brilliant triumph has been made by American surgeons. In 1892 Alexander succeeded for the first time in the history of genito-urinary surgery in making a new urethra, the retentive powers of which were perfect in a case of complete epispadias in the female. There have been 12 cases in all of complete epispadias, in none of which heretofore has the urine been completely under the control of the patient. Physick did an internal urethrotomy by a concealed lancet, and Stevens, in 1817, was the first surgeon in this country to perform external perineal urethrotomy. He revived the operation, which had fallen into desuetude, since at the close of the last century the mortality was so great that the operation was practically abandoned. Prior to 1840 the operation was performed in this country by several surgeons; notably, in 1820 by Jameson, in 1823 by Rodgers, in 1829 by Warren, and later by several surgeons connected with the New York Hospital, among whom may be mentioned Hoffman, Post,

Watson, and also by Alden March, of Albany, and Wood, of New York City. Without doubt the operation has reached its present state of perfection through the labors of Gouley, who suggested the whalebone guide, the tunneled catheter staff, and the beaked bistoury.

Hypertrophy of the prostate is a distressing and fatal condition which modern surgery in the course of its development has to a certain extent relieved, if not cured, in a large percentage of cases. It is one of the triumphs of the art within the period of time of which an inventory of the present surgical operations is taken. A review of the operation for the relief of hypertrophy of the prostate would be incomplete without an acknowledgment of the work of Reginald Harrison, Alexander, and White. As regards the benefits which have accrued to these sufferers from castration, it may be stated that White has shown that 66% or more have return of the power of micturition, most of them a relief of the cystitis, and nearly all freedom from pain. In a series of 98 cases with 7 deaths estimated by White, the mortality of the operation was only about 7%. This is after eliminating a few deaths which had no relation to the operation itself. These figures are striking, and as the time goes on and diagnosis is improved and technic is perfected, and early operations are resorted to, the percentage of alleviation of symptoms and of mortality will be even better than those just mentioned. Castration will never take the place of modern prostatectomy with its present low mortality, and which is gradually improving each year from about 6% as reported by Mayo.

The operation for suprapubic prostatectomy was first performed in this country by Belfield, in October, 1886. Prostatectomy is an operation, the technic of which has been devised in recent years, and it gives great comfort to the patient and saves life. Murphy has reported 34 consecu-

tive cases without a single death due to the operation. This operation has been greatly improved upon by the use of Gouley's prostatectome, which facilitates the removal of the gland.

In lithotomy American surgeons have achieved brilliant results. McDowell did 32 lithotomies in succession without a death. Dudley performed over 100 consecutive operations without a fatal case. In 1846 Willard Parker removed a calculus from the bladder by producting a recto-vesical fistula; and subsequently performed this operation for the cure of chronic cystitis, and in 1861 Bozeman did this same operation to relieve a chronic cystitis in the female. In 1836 Physick removed over 1000 calculi. These brilliant results in lithotomy are most remarkable when it is considered that there was a time in the medical history of this country when a patient actually made the pilgrimage across the ocean in order to secure the services of a surgeon to perform lithotomy.

Litholapaxy is an operation that was introduced by Bigelow in 1878, and has been the means of saving thousands of human lives within the past quarter of a century. It forms one of the most prominent advances in surgery that has distinguished the century. By litholapaxy is meant the crushing of a stone in the bladder with an instrument called a lithotrite and the immediate rapid evacuation of the fragments from the bladder by a syringe especially made and adapted for this purpose. It is a matter of surprise and interest that Bigelow's entire apparatus for litholapaxy remains essentially the same to-day as it did a quarter of a century ago, which demonstrates how complete the mechanism is in all its minor details. Keyes has made some great improvements in litholapaxy, thereby reducing the mortality of the operation, among which may be mentioned in the list of improved instruments the mod-

ern evacuating-tube, the alteration in the mechanism, and other improvements in the technic of the operation. Keegan performed Bigelow's operation 59 times in children, with one death, and Freyer performed it 49 times without a death. The record of Bigelow's, or the American operation of litholapaxy, has certainly won for itself a fixed place in the annals of surgery.

Rupture of the bladder was operated upon successfully by a laparotomy by Walters, of Pittsburg, in 1862, but to Sir William MacCormack is justly due the credit of establishing this operation. Rupture of the bladder has been successfully treated by modern surgery. Formerly these patients nearly all died; thus Ullman's statistics show only 22 recoveries in 237 cases, and in 143 intraperitoneal ruptures only two patients recovered. If the patients are operated upon early and with aseptic precaution, the prognosis is as brilliant as it was formerly forlorn.

Tumors of the bladder have been removed in recent years, and this operation marks an important epoch in this department of surgery. In benign tumors the mortality is about 10%, while in malignant tumors the mortality is 25%. These statistics are certain to improve in the future. Intravesical cauterization with the operating cystoscope for small tumors of the bladder has met brilliant results; thus Nitze had 119 cases without a death.

In surgery of the kidney great progress has been made. The floating kidney is successfully anchored, gunshot wounds of the kidney cured, renal calculi removed, suppuration in the pelvis of the kidney arrested, removal of the kidney itself undertaken for tuberculous and other diseases, and tumors of the organ excised. These are among the achievements of modern surgery, to relieve conditions which were uniformly fatal in pre-anesthetic and pre-antiseptic days.

Nephrotomy for the extraction of calculi has been performed and in aseptic cases has a mortality of only 2.9%. If infection is present the mortality reaches 23%. If nephrectomies for the past ten years are taken, irrespective of the disease for which the operation is performed, surgery has obtained a great victory, since in 365 cases of lumbar nephrectomies there was a mortality of 17%, and in 165 cases of abdominal nephrectomies there was a mortality of 19%. These figures indicate what surgery has accomplished in cases heretofore fatal.

Nephrectomy for the relief of tuberculous kidney marks a great advance in surgery of recent years. Statistics show that in 22 nephrectomies, 16 patients recovered, or about 70%. In another group the recoveries were from 12% to 33%.

Aneurism of the renal artery has been operated upon by Albert, Hahn, and Keen, and all of their patients recovered.

Wounds of the ureters have been successfully sutured, a triumph of modern surgery, and the ureter itself catheterized for diagnostic purposes.

Malignant tumors have been treated with brilliant success in recent years. In fact, so much so in certain varieties that the term seems almost a misnomer. In the management of malignant tumors, American surgeons have displayed great ability. The early work of Warren, of Boston, was among the first attempts systematically to collect and study neoplasms from a clinical point of view. The writings of Gross upon tumors demand more than a passing notice, while the contributions of Shrady and Mudd to cancer of the tongue are most exhaustive.

Malignant tumors are now often cured by radical operations. A century ago these cases presented a frightful mortality. In the course of the development of surgery, owing to anesthesia and antiseptics, more radical operations are

permissible, and cures are now effected where formerly death was the inevitable result. The study of sarcoma is fraught with great interest on account of the meager knowledge, and of its great importance owing to the fact of the terrible mortality which attends the disease. Sarcoma of bone inevitably terminates in death, and its early recognition and its complete removal are subjects which are worthy the profound study of the surgeon. Sarcoma, in the large majority of cases, is a disease more deadly in its nature than any other variety of malignant tumor. Its unprecedented rapidity of growth, its widespread metastases, its insidious development, its uncertainty of early diagnosis, its absolute certainty to kill, make this disease a subject of paramount importance. In this address a study of the varieties, the etiology, and the diagnosis has no place. The prognosis concerns us only.

The prognosis in sarcoma is as gloomy as can be imagined. It is a disease which destroys life rapidly unless arrested by amputation. The prognosis may be modified as regards time by the situation and the particular cell variety of the sarcoma. In whatever way we look at the prognosis it is serious. On the other hand a radical amputation may rescue a patient's life, even in the cases of the most malignant variety. I shall refer to some statistics already published by others, and present the result of my own personal work, as evidence of the progress which surgery has made within the past quarter of a century. For purposes of illustration the malignant tumor known as sarcoma will be first considered.

Sarcoma of glands is a malignant tumor concerning which reliable statistics are very meager. The great English authority, Butlin, states that he fails to discover a single case of permanent recovery after operation. In my list there have been 12 cases of sarcoma of the glands up to

1895, the subsequent histories of which are all known. There have been some cases since that date; but sufficient time has not elapsed since operation in some of the cases, and unreliable histories in some other cases, prevent the tabulation of these cases subsequent to 1895. The principle of cure is the essential feature, and the data up to 1895 have been most carefully investigated. This may be said of all the cases of sarcoma. In these 12 cases, recovery occurred in every case but one, thus giving 83.3% of permanent cures beyond the three-year limit of time. In these 11 successful and permanently cured cases of sarcoma of the glands, there were some which were very large. In two the tumors involved the neck, one of which was larger than a child's head, necessitating a deep and dangerous dissection, which exposed the large cervical vessels. In another case the tumor was situated about the femoral vessels. Some of the tumors were removed in the presence of alarming hemorrhage and involved a most formidable operation. Thus, in sarcoma of glands with 100% mortality, the permanent cure amounted to 83.3% in the 12 cases.

Sarcoma of bone in previous years has been attended with a frightful mortality until surgery, with modern technic, has come to the rescue of these unfortunate sufferers. Butlin records 78 cases of subperiosteal sarcoma, of which the results in 28 cases were unknown, and in 6 cases more the patients had not reached the three-year limit of time, which leaves 44 cases in which the full subsequent histories are known. Of these 44 cases, 14 died of the operation and 29 from recurrences, which leaves but 1 permanent cure in the 44 cases. There are thus 78 cases in which the operation was performed; 14 of the patients died from the immediate effects of the operation, which gives 18% mortality for the operation itself, and of the 44 patients whose full subsequent histories are known, there was but 1 permanent cure, or 2%.

In my list I reported 21 cases of subperiosteal sarcoma of bone in which an operation was performed, 1 of which was an amputation of the hip-joint, and the patient died from the immediate effects of the operation. This gives only 5% mortality for the operation itself. The histories of 4 are unknown. In the remaining 17 cases of the original 21 cases in which the results are known, there are 3 deaths, 1 of which has just been referred to as a result of shock, and 14 cures beyond the three-year limit of time, which gives 82% of permanent cures. This is in marked contrast to Butlin's statistics, which records only 2% of permanent cures.

Sarcoma of the breast is a disease that formerly was most fatal. Modern surgery has accomplished much in reducing the terrible death-rate. Butlin, in his book on malignant disease gives no results either as to mortality or as to permanent recoveries. Williams, in his book, reports 10 cases of sarcoma of the breast, in which no deaths occurred in consequence of the operation itself. The subsequent histories of only 2 out of the 10 cases are known. Death occurred in the 2 cases within 2 years from the date of the operation. The percentage of permanent cures, therefore, amounts to zero, since no patient recovered so as to be free from the disease for a period of 3 years. It is to be regretted that nothing is known of the 8 cases since among the list; there may be some cases of permanent cure. It is unfortunate that these cases have been lost sight of, since no statistics of permanent cure can be recovered unless the result is known. Gross reports 91 cases operated upon, of which 12 were permanently cured, giving 13% of permanent cures.

I operated in 6 cases of sarcoma of the breast, in which no death occurred in consequence of the operation itself. The subsequent histories are all known. Four of the 6 patients

were permanently cured, and the remaining 2 died from a return of the disease. This gives 62 $^2/_3$% of permanent cures in sarcoma of the breast.

Carcinoma of the breast affords a striking illustration of a disease over which surgery has gained a decided victory. There is no more brilliant example to show the progress of surgery during the past century than is found in a study of cancer of the female breast. The necessity of an investigation of carcinoma of the breast can be estimated when it is considered that in England alone there are 7000 deaths annually from carcinoma, and that there are 30,000 patients suffering at all times in that country from this affection, of which number a large proportion involve the breast. When it is considered that 50% of the cases of carcinoma of the breast die within three years, and that a third die within two years, and that of all of the tumors affecting the breast, 80% consist of carcinoma, some idea can be formed of the overwhelming interest and paramount importance of this subject. The mere fact that carcinoma causes more deaths in the United States in one year than the sum total of deaths due to erysipelas, tetanus, hydrophobia, lighting, typhlitis, gunshot wounds, joint disease, together with well-known surgical affections, conveys at once an idea of the wide dimensions of this subject. Carcinoma causes nearly half as many deaths in a year in the United States as are caused by accidents and injuries of all kinds and descriptions.

Dr. Billings has demonstrated by statistics that carcinoma is a disease which is slowly increasing, and that it is a cause of a larger proportion of deaths in nations which have reached the highest state of civilization. For example, in the United States in a year there were over 13,000 deaths from carcinoma, of which there were twice as many deaths among females as among males. There were 1387 cases of death from carcinoma of the breast alone in this country

during the year 1880, and since then statistics show the disease is still increasing. The mortality of this disease, if left unoperated upon, is nearly 100% at the present time, just as it has always been. The mortality of the patients operated upon formerly was considerable, and the percentage of permanent cures very small, while now the operative mortality is very small and the percentage of permanent cures is very high.

I shall refer to my own personal experience, the results of which I have already published, adding, however, that the results in the more recent cases are even better; but the data in full are not possible to collect for many reasons, and chief among these is the three-year limit of time. I have collected within a given period a series of 116 cases of tumors of the breast, 19 of which were not operated upon, leaving 97 cases in which the breast was amputated. In the 97 cases of amputation there was but one death, thus giving a mortality of a little over 1%. The one fatal case was due to the presence of hemophilia and is a death that might have occurred in connection with any other operation, no matter how insignificant in character. This death can therefore with propriety by excluded as far as bearing upon the mortality of this special operation, and if so, there is an unbroken series of 96 consecutive operations without a death. In addition to the reduction of the mortality of the operation from as high as 23% recorded by Billroth to a zero, there was no case of pyemia, septicemia, or erysipelas of the 97 cases of amputation of the breast. Twenty-three cases of sarcoma and other tumors than cancer must be eliminated in order to compute the percentage of permanent cures of pure carcinoma of the breast. These cases of sarcoma of the breast are discussed in connection with the subject of sarcoma. Of the 74 cases of pure carcinoma of the breast, the subsequent histories of 41 are known. Three of these

patients have not reached the three-year limit of time, although they are still alive and free from the disease; there remain 38 cases, therefore, of pure carcinoma of the breast in which the full subsequent histories are known. In these 38 cases there are 17 cases in which a permanent recovery has taken place. This gives 45% of permanent cures. Among these 38 patients whose histories are known there were but 2 local recurrences, which gives but a little over 5% of local recurrences. Since the publication of this series I have had 15 consecutive cases of pure carcinoma of the breast with no mortality from the operation itself. Of these 15 cases, 1 died several weeks following the operation from hemophilia, in which the major joints were filled with blood, and the greater part of the body was affected with subcutaneous hemorrhages. Two of the 15 have not yet reached the three-year limit of time. There are, therefore, 13 cases in which the full subsequent histories are known; 2 of these patients died from a recurrence of the disease and 1 from hemophilia, as stated before, and the remaining 10 have passed the three-year limit time. This gives 77% of permanent cures in cancer of the breast in the last 15 consecutive cases. I believe the last 15 consecutive cases will yield even better results. At all events the mortality was zero and the permanent cures seem likely to be higher than 77%. Modern surgery has much of which to be proud in connection with amputation of the breast, since the frightful mortality of a century ago has been replaced by a steadily increasing percentage of permanent cures. In the future even the present favorable percentage of permanent cures will be increased as early and more radical operations are practiced.

In 1820 Sidney Smith, the great literary genius of his time, made use of the following phrases in the *Edinburgh Review,* which furnishes somewhat amusing reading in the

light of to-day: "Americans have done absolutely nothing for the sciences. . . . In the four quarters of the globe, who reads an American book? What does the world yet owe to American physicians and surgeons? What new substances have their chemists discovered?" The contradiction of the first phrase that "Americans have done absolutely nothing for the sciences" is found in the brilliant and wonderful achievements performed by them, as recorded in this address, by which millions of human lives are saved. "In the four quarters of the globe, who reads an American book?" To such a challenge facts reply louder than words. Were you to take from the world's medical literature, alone, all that has been contributed by Americans during the past century, the result would be astonishing and the loss incalculable. "What does the world owe to American physicians and surgeons?" To this challenge the record of new operations, bold and undreamed of, the invention of new processes, the introduction of new instruments and methods, all of which I have endeavored to outline rapidly in this address, is the abundant reply to this unique interrogative viewed in the light of to-day. "What new substances have their chemists discovered?" The sufficient answer is, "anesthesia," which one discovery apart from all the other noteworthy ones which our chemists have made, places the civilized world under unspeakable obligations to America. Anesthesia is by far the greatest and most far-reaching discovery of the century, a gift to the world which cannot be estimated, a direct benediction from God upon mankind for the saving of life and the escape of humanity from pain.

In a review of the statistics that have been presented, one prominent fact stands out in clear and bold relief, and that is, that all along the line constant and marvelous improvement has been made in the science of surgery. To this statement there is not a single exception in the entire surgical

domain. Everywhere and in every department there has been uninterrupted progress—a progress which has not been hindered or hampered by the loss of any past discovery.

In nearly all the other arts and sciences there is something which has been lost. They have advanced, indeed, most gloriously, and their present development is wonderful in the extreme; yet each one has dropped some good thing by the way which can never be recovered. Their votaries in bygone centuries possessed some secrets in methods and processes which not only died, but evidently were buried with them. By these they secured certain remarkable results which their modern followers, try as they may, are unable to reproduce. Thus in the art of painting, sculpture, architecture, mosaics, pottery, and physics, there are what we style "lost arts," as Wendell Phillips so eloquently has told us, contributions from which have come down to us from the past, which cannot be duplicated in the present. In painting, for instance, the superb coloring of the ancients in their Tyrian purple, and the brilliant scarlet which fades not in centuries. In sculpture, the majestic chiseling of Michael Angelo, that crumbles not in ages. In mosaics, the fusing of gold and glass so that the yellow of the precious metal retains its perfect color. In pottery, a variety of delicate tints and graceful forms which baffle the skill of the potter in these modern times. In physics, the pyramids of Egypt—how were the huge blocks of stone ever carried to the summit, some of them nearly 500 feet above the desert sands, to be laid there in courses which are absolute in regularity and evenness? How were the gigantic monoliths of Baalbec cut out of the mountains and set high in the walls of the Temple of the Sun? How were the mighty obelisks, 16 centuries B. C., transported from the distant quarries, and then set on end with perfect exactitude? Or how was the massive capital, weighing 2000 pounds, ever lifted to its place on the

top of Pompey's Pillar, 100 feet in the air? All these are forcible illustrations of arts which have been lost.

But in the science of surgery it is wholly different, and there is no such counterpart. No operation, no invention, no discovery in this domain that was worth the keeping has ever been lost. The truth is, surgery, as it is practiced nowadays, is so completely a modern science that it does not rely upon anything in the distant past for its present or future development. That distant past was dark with horrible things which may well be tumbled into oblivion. It is only a few decades ago that surgery emerged from the black period of ignorance and cruelty and took to itself a new face and another spirit and form. At once it began its onward march, which speedily became a triumphant one, difficulties giving way before it, obstacles being overcome, every step an advance, with here and there a milestone set up to mark some distinguished feature in the splendid progress. By this new science diseases, which were formerly attended by 100% of mortality, are now accompanied by almost 100% of recoveries. In fact there is no surgical disease whose mortality has not been reduced. No other science can show such brilliant achievements, and no other science can demonstrate its ability to save so many human lives or to ameliorate their condition. We live in an age that is marvelous for its discoveries and achievements, but in no department of science have greater changes been wrought or more brilliant results accomplished than in surgery. It would now seem that we had almost reached the goal. There are but few surgical diseases which our art in its present condition of development does not cure. There are but few operations in point of number that remain for succeeding generations to discover. There is still little to gain in the technic of asepsis and anesthesia, and beyond the improvement of existing operative methods there is but little to expect. The

science of surgery has accomplished a great work—one of the greatest in the history of mankind. And when we consider the vast number of surgical diseases which are now amenable to cure, and the very limited number remaining for which the surgery of the future is to discover ways and means of treatment better than those to which we have already attained, we can realize that we stand on the heights of a great profession—a profession which but a century ago was crude, undeveloped, and uncertain. If there are higher heights to be reached in the science of surgery, and doubtless there are, we may rest assured that the vast and ever-increasing wealth of this great country will be utilized toward their attainment. Humanity demands this, and this country will never be behind any nation of the world in earnest efforts for the promotion and development of a science whose special aim is the relief of physical suffering, and the preservation of human life.

It is fitting on an occasion like this, when a national celebration is in progress, that the attention of this Congress should be directed to the part which our own country has played in the evolution of this great science. This part is best set forth and realized by a study of the facts recorded in this address. The question, however, as to what has been the inspiring motive, and what has been the controlling influence, must be sought in the life-history and habits of the people.

The impartiality and promptitude of the American mind have enabled it to seize with alacrity upon the best in every department of science and art, wherever found, regardless of the source from which it emanates. Accordingly, American surgeons all through the past century have busied themselves in reaping a generous harvest from every nation that had any good surgical idea, method, or appliance to offer, and have gathered in abundant sheaves with rejoicing,

serenely indifferent as to the particular field which produced them. What mattered it to them whose hand sowed the seed, or under what influences it was brought to maturity, so long as the grain itself was desirable and could be secured for the American garner. A precisely opposite spirit has prevailed in some other lands; thus, during our colonial days, when Great Britain and France were easily foremost in surgical attainment, so bitter was their rivalry, so intense their national jealousy, that neither would adopt anything, no matter how good or valuable, which had originated with the other. Of late years this same prejudice, this unwillingness to indulge in a sensible reciprocity, has been manifest between France and Germany, to the great detriment of surgery in each of these rival countries. As an apt illustration, characteristic of the difference between the English and American spirit in this regard, may be cited the fact that in 1823 the writings of one of the great French surgeons, Desault, the most noteworthy contribution to the surgical literature of the world then published, had never been translated for the use of British surgeons. No Englishman had the courage or willingness to demean himself by so doing, since he would thereby acknowledge that some good thing might come out of France. Yet at that very time, Smith, of South Carolina, rejoicing as one who had found great spoil, was busily engaged in putting Desault's works into English for the benefit of the surgeons of America.

So in this great triangle of nations formed by England, France, and Germany, the surgical knowledge and suggestions of each remained within its own walled domain, untouched by the others; on the contrary, in a pleasantly independent spirit, and having no unfortunate jealousies to cherish, America reached her eager hand over the separating wall, and freely and gratefully laid hold upon whatever she

considered best in the surgery of those and other nations, appropriating to her own use, for the good of humanity at large, as many of their principles, theories, discoveries, methods, and appliances as she considered it worth her while to take. Availing herself of these factors, utilizing them as stepping-stones, and combining them with the wonderful achievements of her own inventive genius and skill, she has rapidly risen to that illustrious height in the surgical world which she so grandly occupies to-day.

It goes without saying, gentlemen, that within the past decade, America, without any effort of her own, without the least self-seeking, but through the force of her national greatness—moral, intellectual, physical—has come to the front as a world-power among the nations of the earth. She now ranks second to none as an important and controlling factor in the congress of nations, and when she speaks, her voice commands the attention of a listening world. In this regard her science of surgery has kept even pace with her political advancement upon the powers. At the present time her surgeons are not outclassed by those of any other country, while in her contributions to the general literature of surgery, she stands unsurpassed. It is an actual fact, if you were to strike from the notable surgical achievements and writings of the world what has been contributed by America during the past few decades, there would be left but little of new and original work for the older nations to claim as their own.

There are many things which combine to explain the prominent position which America has taken during the past century in the consummation of this great work. Chief among them may be mentioned the innate courage which our Puritan ancestors possessed. The undaunted bravery which enabled the people of the Mayflower, and others of kindred heart and mind, to cross the great unknown oceans

and to settle in the primeval forest for the sake of liberty, has infused itself into the American spirit and has qualified Americans to attempt and to perform daring deeds in surgery. There is no science that calls for greater fearlessness, courage, and nerve than that of surgery, none that demands more of self-reliance, principle, independence, and determination in the man. These were the characteristics which were chiefly conspicuous in the early settlers of this country. And it is these old-time Puritan qualities, which, descending to them in ordinary generation, have passed into the surgeons of America, giving them boldness in their art, and enabling them to win that success in surgery which now commands the admiration of the civilized world.

Permit me to sum up in a few words the wonderful achievements of surgery during the century which has gone. What has this great science, so young comparatively and yet so strongly and splendidly developed, accomplished in its onward march? Among the blessings which it has brought to the human race may be mentioned these:

The annihilation of pain during surgical operation.
The elimination of sepsis after operations and injuries.
The eradication of physical suffering.
The restoration of sight to the blind.
The recovery of hearing to the deaf.
The return of lost functions to organs and glands.
The aseptic repair of injured parts.
The relief of the crippled and lame.
The restitution of speech and consciousness.
The return of activity to paralyzed members.
The removal of malignant disease.
The restoration of reason to the insane.
The correction of bodily deformities.
The alleviation of pain in disease.
The reaction from shock and collapse.

The cure of lockjaw and other infective processes.
The intervention of relief in intestinal perforation.
The extirpation of tumors from glands and cavities.
The cure of diseases and injuries of internal organs.
The resection of diseased viscera.
The excision of joints and necrosed bone.
The amputation of diseased members.
The cure of aneurism.
The removal of cerebral and spinal neoplasms.
The reduction of mortality in all surgical diseases.
The entire removal of mortality in some surgical diseases.
The restoration of health and reason.
The salvation of human life.

Surely, Mr. President, and fellow members of the International Congress of the Arts and Science, the great science to which we have devoted our talents and our lives, the science which kindles our enthusiasm, and of whose achievement we are justly proud, our science of surgery during the past century has come as a benediction upon the human family, second to none which the century has spoken. Its benefits cannot be measured by words, or realized in thought. We are apt to speak of it as a human achievement. In one sense, so it is; but it is come in the orderings of an all-wise Providence; and with grateful hearts we acknowledge it as a gift and blessing from the Almighty Father to His suffering children in the world.

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(Prepared through courtesy of Dr. Hobart A. Hare, Philadelphia.)

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TYSON'S Disease and Diabetes.
TYSON'S Examination of Urine.
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(*Prepared through the courtesy of Dr. Frederic S. Dennis.*)

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THE FUNDAMENTAL CONCEPTIONS WHICH ENTER INTO TECHNOLOGY.

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THE *Fundamental Conceptions which enter into Technology* is a large subject and one which, from its very nature, I cannot hope to treat with completeness. In asking me to undertake its exposition, I assume it was understood that, as a technologist myself, I should naturally speak without the terminology of philosophy—shall I say in an untechnical manner?—that is, from the standpoint of a practical man.

The prevailing characteristic of the eighteenth century has been considered to be the philosophic spirit, while that of the present age is admitted to be the scientific spirit; some even call it the age of the application of science. Is it a sign of a coming reaction that I am asked to speak of what might not inappropriately be called the philosophy of science?

Science, which, at the outset, attacked the more striking facts of the external world, now busies itself with the invisible, the intangible, the inaudible. This line of growth must tend in the direction of stimulating the imagination,

and of directing the mind to an investigation of the principles on which sciences are based. Thus we find that science, which at first appeared to be leading away from philosophy, is seemingly leading back to it again, and that we, its followers, have been unwittingly tracing out another of the great circles of truth. However this may be, we have now to consider the conceptions which enter into the most practical of all the sciences, and the one which, of all others, was long supposed to be purely experimental and to require no mental foundations of any kind.

A conception is a thing so subtle, so illusory, that it seems capable of receiving the work of many minds and many generations before it can be said to emerge with any—not to speak of absolute—clearness from the background of thought. Our first efforts to give it a shape bear about the same relation to the complete thought as the first rough tracing might do to a finished statue. Take, for example, the conception of the development of the individual, which is so marked a feature of all modern educational theories. How slowly it has taken shape in the thought of the world! How far are we still from acting in accordance with it! How far from realizing that *power* and not knowledge should be the true aim in education!

Towards the better understanding of technology comparatively little has been done, and that for the very natural reason that the practical has constantly turned aside the attention. The Technologue (to use a word not yet adopted into English) has been described as an intermediary between the savant and the mechanic, translating, as it were, the discoveries of the former into the uses of the latter. Although we may see reason later to modify this view, still, in a certain sense, it is quite true, and the truth of it accounts for the fact that the exponents of practical science have hitherto had little time or inclination to travel

with any speed towards the realm of the abstract. Yet much good work has been accomplished. Merz has investigated the scientific spirit with a view to discover its effect on the progress of thought in Europe; Reuleaux has spoken of the evolution of science with especial reference to technology; Anderson, in his Forrest Lecture, has chosen as his subject the relation of science to engineering, and a host of others have discussed before learned societies special aspects of technology chiefly relating to the history of its development during the present century. It is little wonder that such splendid achievements as this history chronicles should so have dazzled our eyes that we have not attempted to inquire too closely into their source. To-day, however, we shall try to regard these achievements only as the effects of a cause which we seek to find. We shall restrict our admiration of the constructive ability displayed in a Brooklyn Bridge or a Saint-Gothard tunnel; of the inventive genius shown in a Morse system of telegraphy, or a Bell telephone; of the force of insight and determination which overcame the practical difficulties of the steam-engine or saved its vineyards to France. We shall restrict our admiration, I say, and try to discover the controlling ideas which were common to all, and which impelled the directors of these great enterprises along such apparently diverse paths.

We may notice especially three of these ideas. In the first place, these men must have observed that nature works in no arbitrary manner, but by fixed laws; that while the earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease.

Secondly, they must have perceived that, as Reuleaux points out, if these laws could be brought into the right relation with us, or rather, if we could bring ourselves into the right relation with them—into the line of their work-

ing—we might hope to be able to gear our small machines to the vast wheel of nature, and make it do for us what we could never do for ourselves.

A recent writer has asked us to recognize in certain inventions of man *extra-organic sense-organs;* to see a projection of the human eye in the telescope and the microscope, which so marvelously extend our vision that it can resolve the misty light of the far-off nebulae into suns, or discern in a clod of clay a world of wonder; to hear in the telegraph and the telephone the tones of the human voice so intensified as to reach round the world, and in the printed page the silent voices of long past generations; to know the express train and the ocean liner as extensions of our locomotor-mechanism; and to discover in a tool or a lever the human arm grown strong enough to perform seeming miracles.

Thirdly, these master-minds must have realized that in the study of the laws of nature, and in the attempt to put ourselves into touch with them, there would certainly be revealed more and more of what seem to be the infinite possibilities of our environment.

In almost every endeavor to explain the nature of observed phenomena, fresh and important facts emerge which in their turn call for explanation. This is true, for instance, of the investigations in radio-activity now being carried out by Professor Rutherford, in which the deductions are so novel and startling that it would have been impossible beforehand to have made any prediction as to their character. Again, what a vista has already been opened up by the interaction of the sciences! What a great development, for example, has taken place in electro-metallurgy, due entirely to the processes made possible by a combination of physics and chemistry, and based upon Faraday's well-known law of electrolysis!

The first and second of these conceptions, namely, that law is a fixed thing, and that if we and our work could be brought into the right relationship with the laws of nature, they would expend their mighty force in our service, make possible a *process* under the control of man, a process which, while having many intermediate objects, has always the same goal. Thus we may primarily study the steam engine with a view to a knowledge of its mechanism, while our ultimate aim, if we are to work with complete success, must be so to design its several parts that it may lend itself to the power of steam with the least possible resistance.

We may conceive of a law of nature as a fixed thing, a Niagara of force; we want to construct a wheel which shall receive its impact and turn its water into fire. Nothing can change or improve the law; the only thing we can do is to make ourselves familiar with it, which may be done either by watching its operation in nature, or by causing it, as it were, to display itself before us—bringing together the materials whose interaction it is our purpose to investigate. This we call making an experiment, and it has now become the usual method of studying the laws of nature. To this fact, indeed, must be attributed much of the rapid progress of modern science, as we have no need any longer to wait, as did our ancestors, for nature periodically to marshal her forces and cause them to defile before us.

This, in general, is all we can do with our environment. What can we do with ourselves?

In order to study to advantage we must get into line with the laws of the mind, remembering that they are, equally with heat and electricity, the laws of nature. We must make the laws of the mind work for us instead of against us, just as we are seeking to do with the forces external to us.

We find that to bring us into contact with the outer world

nature has given us the five senses, and the wonder is with how small a use of them people manage to get through their lives. The reason is, perhaps, that these senses only present facts to us, and facts, although necessary to thought, require, like other raw materials, to be worked up before they give us ordered knowledge.

We also find that the apprehension of a fact by the mind requires the exercise of the power of observation. This presupposes sensibility both of the external organ and of the brain centres, and also a certain amount of will-power which prevents the observation from being a mere photographic reproduction of the external world. The observations we speak of must be of a special character. They should be minute like those of Hunter in his study of a deer's horns; they should be accurate like those which led Adams and Leverrier to the simultaneous discovery of Neptune, and, above all, they should be selective, that is, if we are following up a special point, we should be able to fasten, as it were, on the fact which throws light on the question at issue, remembering that it is not always or even usually the feature most prominent which will put us on the track of the discovery of true connections, but more often some small detail which the ordinary person passes by unheeding. For instance, take the case of Becquerel when examining a definite point suggested by the discovery of the Röntgen rays. At that time it was thought that the phosphorescence produced in a vacuum tube was in some way connected with the excitation of X-rays. Becquerel, therefore, examined bodies which were phosphorescent under ordinary light, to determine if they gave out rays of a similar character. On a certain dull day he happened to leave a photographic plate exposed over uranium, and to his surprise he found that a marked photographic impression was produced. Knowing that the phosphorescent light from

the uranium compound persists for only a short time, he was able to draw conclusions which proved to be the commencement of the now great and important investigation into radio-activity.

Observation, as commonly used, seems to mean to see with attention. It therefore involves concentration, or the focusing of the whole force of the mind on one point for an appreciable moment of time. As soon as concentration takes place, a process of analysis begins, and we pass through the perception of likeness and difference to classification and then to generalization, by which we fit observed facts into their proper places in the scheme of nature, gathering up the new with the old into a larger and larger synthesis. Memory now comes into play to retain what we have gained; and a new impulse to gather new facts, as well as, sometimes, a fresh point of view, we gain from the contact of the new with the old and the arousing of the power of deduction.

Further, we must not overlook what is really a fact of the utmost importance—that the cultivation of observation by the sense of touch and the use of the hand as an instrument, together with the possibility of making experiments which must be carried out by the hand, have led to what might be called a discovery, namely, that the training of the hand actually stimulates the brain centres. This has given to manual training its true value.

By this *process,* in the first place, of studying the laws of nature, either as they are presented to us in the natural course of events, or as we may induce them to display themselves before us in experiments; and, secondly, by studying them with all possible reference to the laws of the mind, including those of the interaction of the hand and the brain, we attain to that knowledge of our environment and to that plane of capacity in ourselves which are necessary pre-

liminaries to the bringing of the powers of nature under our control in the interests of humanity.

What is the indispensable step which often intervenes, which, untaken, makes it still necessary that we should call so much of our knowledge by the name of pure science? For how many centuries had sticks been rubbed together to produce fire before Rumford, while superintending the boring of cannon in the Arsenal Works at Munich, hit upon the true explanation of what becomes of work spent in friction? Or, as Lamb humorously puts the case, in discussing the origin of the custom of eating roasted instead of raw meat, "in process of time, says my manuscript, a sage arose, like our own Locke, who made a discovery, that the flesh of swine, or indeed of any other animal, might be cooked (*burnt,* as they called it) without the necessity of consuming a whole house to dress it. Then first began the rude form of a gridiron. Roasting by the string, or spit, came in a century or two later, I forget in whose dynasty. By such slow degrees, concludes the manuscript, do the most useful, and seemingly the most obvious arts, make their way among mankind." The veil which hid the prospect, once dropped, is not our natural exclamation, "Why did we not see that before?" What, then, is the necessary step? Is it not the exercise of just that quality which the scientific man has been blamed, and often with too much reason, for neglecting?—the divine gift of imagination, which

"bodies forth the forms of things unknown."

In his *Defence of Poetry,* Shelley points out the evil effects "which must ever flow from an unmitigated exercise of the calculating faculty," and says, "whilst the mechanic abridges, and the political economist combines labour, let them beware that their speculations, for want of correspondence with those first principles which belong to the

imagination, do not tend . . . to exasperate at once the extremes of luxury and want."

Out of such conceptions as these two, by the process just described, the science which has received the descriptive title of applied science and the general title of technology, has grown up, but almost unconsciously, for, as a matter of fact, it has arisen far more from practical necessity than from thought-out schemes. We can see that it has a two-fold nature corresponding to the process referred to.

First, we can learn by specialized study how to understand and apply the principles of mechanics—which is coming to be regarded by some authors as the primary all-embracing science—to the construction of works of utility of every kind. We find this conception distinctly recognized in the founding at Harvard of the Rumford Professorship in 1816. In his will, Count Rumford reserves certain annuities "for the purpose of founding a new institution and professorship, in order to teach by regular courses of academical and public lectures, accompanied with proper experiments, the utility of the physical and mathematical sciences for the improvement of the useful arts, and for the extension of the industry, prosperity, happiness and well-being of society."

Secondly, we can train the mind of the student to work easily along lines of scientific thought; in fact, we can do much to form the scientific mind.

It will now be seen that, so far as we have considered it, technology is really a process of education—a secondary science—a process which has been described by Ellis as an entire system of education by new methods to new uses. He tells us, at the same time, that the first use of the word technology, apparently, was made in connection with the professorship just mentioned, in that Dr. Bigelow, who, for ten years, held it with marked ability and success, pub-

lished his lectures under the name of the *Elements of Technology.*

We find, however, that technology, as now taught, embraces a third department of a completely different character, and one which has arisen out of the working of the third conception to which I have called attention, namely, that in the attempt to utilize the natural laws, there would certainly be revealed more and more of the infinite possibilities of our environment.

So indeed it has proved. It happens that certain investigations into the chemical and physical properties of matter, into the dynamics of steam, electricity, etc., have been made by the engineer rather than by the physicist and the chemist, because these investigations have been required by the practical work of the engineer, and because they have sometimes to be carried out on a scale inconsistent with the more delicate experiments which are the chief occupation of the physical laboratory. So it has come to pass, as a matter of convenience mainly, that engineering, besides being a profession, has been made directly responsible for certain scientific work, and may in this light be looked upon as containing within itself a pure science.

Numerous examples might be quoted as illustrating this statement from any good engineering laboratory, and I will just refer to one or two which I have taken from our own experience at McGill University. Callendar and Nicolson, with the platinum thermometer and ordinary steam-engine, were able to deduce laws of the utmost importance relating to the cylinder condensation of steam. The experiments of Adams and Nicolson, and subsequently of Adams and Coker, have thrown new light on the flow of rock-masses under high pressures and temperatures, and further developments may be hoped for, as generous provision for the purpose has been made by the Carnegie Institute. By

means of specially designed extensometers it has been possible to study, within the limits of elasticity, the lines of stress in beams under transverse loads, and much progress has been made in the solution of many hydraulic problems, notably in the determination of coefficients and the critical velocity.

This department of technology, which is daily assuming more importance, has hitherto been little emphasized, and it naturally brings us to consider the distinction between pure and applied science and also the definition of the place we must assign to technology in the general scheme of knowledge, a definition involving the proper classification of science in the widest sense, a subject which has occupied the attention of many learned minds.

Our very word *science* itself, that is, knowledge so systematized that prediction and verification by measurement, experiment, observation, etc., are possible, is in Germany limited by the name of *exact* science, and is included in a larger idea, *Wissenschaft,* which seems to embrace ordered knowledge of every kind; for example, the accepted principles which govern the search for historical and philosophical truth. The German idea of *Wissenschaft* includes at once the highest aims of the "exact, the historical, and the philosophical lines of thought." "That superior kind of knowledge, dignified by the title of Science, must," says one writer, "have generality as opposed to particularity, system as opposed to random arrangement, verification as opposed to looseness of assumption."

In view of what has gone before, there is no need, I imagine, further to substantiate the claims of technology to a rank amongst the sciences. We have tried to show that its material is scientific, that it is itself in all departments a scientific method of dealing with nature, and, in one department, an actual investigation into nature; but we shall

see that its place in a general classification of science is rather a composite one.

Pure science has been defined as "the knowledge of . . . powers, causes, or laws, considered apart or as pure from all applications." It involves a research into facts by which we learn to understand their nature and to recognize their laws, and its description naturally includes a history of the facts or experiments by means of which it has been made manifest. In one sense every one of these experiments is an application of already known laws of science to something of the nature of a machine—a case exactly parallel, in outward seeming, with what is done in the ordinary departments of technology. Yet, with a true instinct, it is not called technology, and why? Because the *aim* is different. Even if the ultimate aim be utility, it is not primarily so. The first and immediate aim is to subserve no practical purpose, but to dig into nature's garden and find the roots which, down in the dark, are working out their wonders.

These experiments may be called *applications of pure science,* but we will not give them the name of applied science or technology, which clearly involves the idea of utility. Whether this is necessarily a higher or a lower ideal, we will not at present consider, for we have shown that we have a claim to both ideals; but we will simply admit, nay more we will emphasize the fact, that the technologist, in the ordinary sense, wants to know about the heat of the sun in order that he might drive its chariot with greater success than Phaethon of old. It is not *knowledge* but *power* which is his ultimate aim.

Even in the department of pure science, to which we have referred as the third department of technology, the idea of utility is more prominent than it ordinarily is in the laboratories of pure science, though still in its highest form, and

acting rather as an incentive to begin the work than affecting the manner of carrying it out. For instance, the strong desire to eliminate the errors caused by the sensitiveness of metals to variations of temperature has prompted the effort to find a remedy, which has recently resulted in the use of a definite combination of nickel and steel, a material practically insensitive to temperature changes.

The idea of *utility* seems to be the real key to the distinction between pure science and technology.

We find technology variously described as the science of the industrial arts; as the application of scientifically obtained facts and laws in one or more departments to some practical end, which end rules the selection and arrangement of the whole, as, for instance, in the practical sciences of navigation, engineering, and medicine. Again, applied science is defined as a knowledge of facts, events, and phenomena as explained, accounted for, or produced by powers, causes, and laws.

We see that when laws are attached to facts, whether in nature or experiment, for the purpose of explanation merely, we call it pure science, but when laws are attached to facts with an idea of utility in art, manufacture, or in the general service of humanity, we call it applied science or technology. In the first case, the fact is viewed as an instance of the law; in the second, the fact itself is the important thing. Therefore, the distinction between pure and applied science seems to be largely one of purpose; if our purpose is to establish a law we call it pure science, if our purpose is to establish a fact we call it applied science.

We see, therefore, that technology, while in one department a pure science, investigating the laws which govern, for example, the strength of structures both as dependent on material and form, or, in general, any problem arising out of the artificial working-up of natural products, is, in

the main, to be called an applied science, and is in fact so described. I can find no essential difference between the use of the two terms "applied science" and "technology," as they are ordinarily employed at present, and scarcely a case in which either of them could not be used. A notable exception is the science of medicine, which is, strictly speaking, an applied science, but which is never described as technology, perhaps foreshadowing a more distinct specialization in the use of the term technology, so that it may indicate only the science of man's makings and not the science of man's doings. The scope of technology, even as thus defined, is, perhaps, its most striking characteristic.

The endless range of knowledge, opened up by an attempt to apply even the known laws of nature to the limitless array of facts, is at once apparent, even if we say nothing of facing the new problems arising in the process. Our material is evidently the whole world, with all the giant forces impelling it on its yearly circuit, lighting, heating, and supporting its myriad forms of life and ruling their motion and their rest.

Where shall we find a guide in this complexity? How shall we choose between necessary and unnecessary knowledge? In theory it seems impossible to draw any line, and one never knows at what moment a new department may become essential; but, in practice, this very possibility has suggested the course which has been followed, namely, the attempt that has been made to gain a knowledge of those laws which *up to the present time* have been adapted to practical needs. As more of these laws are utilized they, too, will be incorporated, and the limitations of the human mind must then be provided for, in a greater degree than is the case at present, by a scheme of options which will allow each individual to use as his *material* mainly the special knowledge that he will require in the department of

technology chosen as his particular profession, and which will compel him to know of the other departments only enough to fit this into its right place in the general scheme.

Such a system of options is, fortunately, feasible by reason of the fact that the mental powers, trained to work scientifically in a given direction, can afterwards be turned to other objects. At least this is the case when the *method* of working is given the first importance, as then only is it possible to form the scientific mind.

If we examine the best modern schools of technology we find that the curriculum contains departments founded on the conceptions with which we have been dealing. We notice,

First, a study of selected laws of nature (*i. e.,* those which have already been applied to practical purposes);

(*a*) as seen in nature;

(*b*) as seen in examples and descriptions of the means by which they have been utilized. This corresponds to learning by experiment, and includes especially the study of all types of machinery, implements, and instruments.

Secondly, a distinct aim to train the mind of the student in accordance with the laws of the mind.

This is not usually done theoretically, *i. e.,* by any inquiry into the laws of the mind, but practically, *i. e.,* by causing the student to learn some particular form of industrial art in a scientific manner.

Thirdly, a distinct desire to encourage,

(*a*) research into the nature of the practical facts essential to any art, with a view to finding out reasons for the same in the *known* laws of nature, thereby giving workmen the opportunity to work intelligently;

(*b*) original research into the problems arising out of industrial processes, with a view to finding out unknown laws of nature, and especially those which must be investigated on a large scale.

We may observe that this classification includes in the *third* division a kind of research, (*a*), which, though not exactly pure science, as it does not seek for unknown laws but only for known laws which will fit a particular case, yet partakes of the same nature as far as the action of the mind is concerned. It is practically useful and necessary as a part of technology, because it supplies to the workers in any art the fundamental reasons which justify the employment of a certain procedure (whether such procedure has been developed by practical experiment or whether it has been devloped as a result of theoretical research). This search for causes will naturally increase in importance with the growth of knowledge as to the scientific carrying out of any art, or, in other words, as trades and arts tend to become more scientific.

In practice it is found that foremen, educated in a knowledge of fundamental laws as well as in scientific processes, are far more valuable, and that the workmen also will be all the better, for whatever knowledge of this kind can be given them. Numbers of firms and corporations are now acting on this principle, some even refusing to accept a messenger-boy unless he has passed through a high school.

Further, this training, which enables a worker to recognize essential principles, has the great advantage of showing to the worker in what direction it is possible to make advances and improvements and—no less important a matter—in what direction progress is impossible. The history of invention will emphasize the truth of this statement. How much time and brains, for instance, have been wasted in devising mechanism which involves the fallacy of perpetual motion!

We notice also that, in the second department, the classification includes instruction in the scientific process of carrying out any art required by a student for his future work.

In any true university this practically useful plan is made to subserve the end of mental development in the student. This department naturally takes up a great deal of space in an institution, as there may be almost as many options as there are students. Partly for this reason, partly because it is the easiest end at which to begin a technical school, and partly because it appeals most strongly to the non-university man, as being apparently a short cut to success, it is not infrequently *all* that is understood by technology, and is *all* that is directly included in its definition as the *science of the industrial arts.* This scientific instruction in the industrial arts may be said to have been the beginning of technology, and where it has been over-emphasized, it has given apparent justification to the idea (of which there is still a survival) that the subject is not necessarily scientific in any wide sense, and that the practical training of workers is more important than the theoretical.

Technology may be called the child of science on the one hand, and of industrial progress on the other; therefore we must not be surprised to find a very curious blending of the spirit of both in an institute of technology.

We can do exactly the same thing at different times with a different, even with an opposite motive, but though the same thing is produced externally, the result on the mind of the student is, in each case, the result of the inner motive. What happens depends, as it were, on the point upon which the stress is laid. Wherever the spirit of science prevails, we are on the lookout for phenomena which may lead us to a better understanding of a known law, or to a knowledge of some hitherto unknown law of nature. Wherever the spirit merely of industrial progress prevails, we are on the lookout for some adaptations of our machines or processes which may add to the chances of commercial advantage. In the former case, while we learn

the best, because the scientific, method of carrying out an art, we put at the same time the real emphasis on producing the scientific man. In the latter case you produce merely an intelligent handicraftsman, whose very highest aim is to improve his art—by no means an ignoble end, but one which might easily be ennobled, and one which may and often does defeat its own purpose—for the true scientific spirit is also a spirit of prophecy, and if you do not succeed in producing it, those things which might have been to you a new revelation will lie by your side unperceived. Merz likens Bacon to "one who inspects a large and newly discovered land, laying plans for the development of its resources and the gathering of its riches."

In the fact of scientific foresight is found a strong practical argument for curbing the impatience to acquire the training requisite for success in a practical profession—the readiness to sacrifice a more remote to a more immediate end. This impatience is still so great as to cause a serious danger that our technical schools may be tempted to give a purely professional training, or that professionalism may become overwhelmingly strong in them, and threatens to introduce, into even our common schools, a far too soon begun specialization.

That this danger exists is one reason why it is true, and probably always will be, that the scientific spirit is relatively more often produced in the students of pure science than in the students of applied science, but note that this is only relatively true. Other things must be considered. Where you can get one man to devote himself to pure science, you can find a thousand to fill the ranks of practical workers, so that you greatly multiply the actual chances of discovering the why and the wherefore of things, and, at the same time, you secure the enthusiasm derived from numbers. Also besides the mere increase of chances aris-

ing from larger numbers, and the immediate effect of numbers, we can claim for the workers in applied science, under the *best* conditions, as remarkable a development of the scientific spirit as has ever been recorded in the annals of pure science. Take, for example, the great French chemist and naturalist, Pasteur, who "has been able," as Ray Lankester justly says, "not simply to pursue a rigid path of investigation dictated by the logical or natural connection of the phenomena investigated, but deliberately to select for inquiry matters of the most profound importance to the community, and to bring his inquiries to a successful practical issue in a large number of instances. . . . The discoveries made by this remarkable man would have rendered him, had he patented their application and disposed of them according to commercial principles, the richest man in the world. They represent a gain of some millions sterling annually to the community."

Moreover, we must remember that what we have called professionalism, though limited to a sphere which appeals to our individual interest, is, after all, in part of its nature, very closely akin to the scientific spirit—inasmuch as it seeks for truth, and is often imbued with the spirit which would spend itself in the effort to achieve honest work, in the joy of overcoming, in the patient performance of duty, or in the search for what will bring honor to the profession. Therefore, in contrasting the spirit of professionalism with the scientific spirit, it is rather the element in professionalism that we may call commercialism which we wish to avoid —the way of estimating values by money value and of measuring our interests by dollars and cents.

Further, we cannot afford to condemn even commercialism in a wholesale manner, as is often done. We are led to look for the element of real value which must be there, when we find, for instance, the last India budget pointing

with satisfaction to the great increase in bank deposits in spite of plague and famine, and when we find, in general, that we are always able, to a certain extent, to measure any nation's progress by its increase in riches.

Let us notice, however, that the purely scientific man contributes greatly to the world's wealth, but seldom to his own, and has to be supported by a world which knows the value of his work and makes an appreciative *entourage*. Notice, also, that the study of commercial methods is distinctly good as opposed to waste, being quite necessary to the study of economics, which is the application of philosophical and scientific principles to the conduct of life—a kind of final aim of the general application of science to life. To know how to live and conquer our environment financially, in a manner easy enough to leave some margin for intellectual advancement, seems to be a necessary condition of living on a high plane. True, one can have plain living and high thinking, but when it comes to sordid living, when the food is perhaps too little to feed the brain, or even when every scrap of energy is used up in providing for material wants, then indeed the wings of the imagination are clipped and the eagle becomes a barnyard fowl.

If, then, this commercialism has so much that is good and necessary, why should we look upon it as a danger? Because, like fire, it is a good servant, but a bad master; because, in this world, we must look upward, or with level eyes, or downward. We feel instinctively that true scientific thought is an *aspiration,* that a wise economy or management, a taking far-seeing advantage of circumstances, or any honorable making of money, especially for unselfish purposes, is practical common sense, and is helpful in, as it were, buying time in which we may rise to higher things. On the other hand, we feel no less than if we turn the making of money into a goal in itself, the road to it is beset

with the pitfalls of greed, selfishness, and dishonor, and that the looking at it thus, or as the chief standard by which to measure values, is quite unworthy of our higher nature. "What lovely puppies!" exclaimed the child. "A hundred dollars' worth of dogs," remarked the lad, who was trying to reach too quickly the time when the glory of dawn melts into the light of common day.

On these grounds we feel that any teaching that allows commercialism to become too important a factor is fraught with danger. That we speak of it not as an evil, but as a danger, suggests a reason why it is not shunned with more care. It is only a risk, and I am afraid that, over-confident in the steadiness of our heads, we seldom mind skirting moral precipices, but in a scientific institution, at least, we ought steadily to build up the invisible moral ideal.

Risk is a conception distinctly opposed to any science seeking after absolute knowledge, and should be as far as possible discouraged, whatever legitimacy there may be in it being replaced by a keener foresight. If we deal with risks at all, it should be in a scientific way, calculating their amount and providing for them, and we should certainly practice what we preach, estimating with care the danger of commercialism, and deciding whether it would not be better to avoid it, lest we be confronted with the necessity of providing a counterpoise for which a technical institute offers no adequate material.

It may be said that this is a side issue, and not a fundamental conception, but our assumptions are always greater than our conscious knowledge, and, in one sense, there are no side issues. No truly scientific man can be blind to the position of his immediate object in the general scheme of things, and the more broad-minded he is the more careful will he be that, as he moves along, he is not stirring up

forces for evil; more, he will be *positive* in his effort, and will try to see that it is tending to produce a man whose work shall be worthy of his own nature.

All moral issues, which have been often used in support of the idea of the new technical education, are, in the same sense, side issues. A technical school is not, and cannot be, primarily a school of morals; but even men, sufficiently careless about their own standard of life, are glad enough to encourage and cultivate in others that stability of conduct which is the best bulwark of a democratic state. If we consider the manner in which any moral effect may be looked for, as a result of technical training, we shall see that the process must be something of the following nature. The inner eye, which sees truth, is necessarily aided by the immediate detection of errors in form, or in the nice adjustment of outward things, and the consequent emphasis which is laid upon the value of accuracy. We cannot take the first step towards a virtue until we see it clearly, and, therefore, whatever magnifies it makes that step more possible. Again, we may reflect that the enforced yet pleasant exercise of a virtue may do much to make it agreeable, and may diminish any natural opposition to it which may happen to exist. Further, still, we may go, and assert that the will itself may be, and is, cultivated in the overcoming of obstacles, and, therefore, may be made the more powerful instrument of an awakened and a holy purpose—for deep down beyond all this, we come to the place where we are forced to admit that we have reached the limit of human effort, to the place where the wise will lift up "hands of faith." No science can teach a *love* of truth which shall be strong enough to conquer life. Yet, within its limits, in common with all true scientific teaching, and perhaps in a larger measure proportionate to its appeal to a larger *clientèle,* technology may lay claim to produce moral strength, truth, and manliness.

Nor is this all by any means. Technology has been exalted as the spring of civilization, and it is, and not only or merely because the promoters of utility increase the ease of life, "make space and give time," and so broaden our mental horizon, but also because in the contest with the earthly and the sensual it is no small matter to be reinforced by the widespread existence of intellectual tastes, and because the patient waiting on nature, often so necessary in scientific work, tends to produce self-restraint. To self-restraint and true temperance we must look to save our civilization from passing into rottenness, as has been the fate of many another, which, dahlia-like, has blossomed only to turn into a sodden mass, because, perhaps, it has not recognized the truth that it is of no use at all to *refine* the vices of the state, that the plow, which uproots the evil weeds without mercy, must prepare the way for the waving grain and the fruitful harvest of a true civilization. We might go on—we might call attention to the self-sacrifice which often leads the man of pure science and surely, not seldom, the true technologist, to count his life well lost in the service of truth. Nor in this busy practical age must we forget that, if we choose, we can make each obstacle overcome, not a step from which, like a child in play, we can leap back to our former position, but a point of vantage from which we can scale,

> "By slow degrees, by more and more
> The cloudy summits of our time."

There is one subject on which I should like to say a word, one that is generally used as a *contrast* to technology, namely, "fine art," or the science of beauty, the beautiful being regarded as the antithesis of the useful. I cannot feel content so to express the relation between the two.

Have we not already noticed that the inspiration of genius, no less in science than in art, requires the imagina-

tion as its instrument, and can only express itself in terms of its language? Also, has not one of the greatest writers on the science of the beautiful called our attention to the fact that beauty without strength and truth is a sham? No, there can be no true antithesis. The power of seeing the abstract must be much the same mental power, to whatever subject it is applied, and whether it discovers ideal truth or ideal beauty, it matters little; the great thing is to feel the Soul of things at all, and not to be only capable of seeing with a surface realism which thinks nothing worth discussing unless it can be handled.

In practice, however, we still find a difficulty. In the early stages of technological education, drawing is recognized to be the foundation of the industrial as well as of the fine arts, but later, an apparently inevitable specialization differentiates between the two, and, except in the one department of architecture, beauty and the science of beauty have been largely ignored by the new education.

Is it really necessary to be ugly in order to be useful? Can we not lift and store our grain without disfiguring our most beautiful views? Must we strip our great forest of trees and make them into bare poles from which to swing our electric wires? Should it be possible to describe any human habitations as packing-boxes pierced with holes? Is it *really* a useful purpose which would take for any common end the glorious redwood forests, planted before the Christian era, "for the service of man" indeed, but for what service—to build him a house—to kindle him a fire—or to waken his soul to a knowledge of its own value?

Here, then, is not a danger to be guarded against, but a want to be supplied. We need the imagination in the highest departments of technology, but there is at present no distinct training for it, and there should be, if only to help a man to realize the unity of his own mental being

and the mighty unity of Nature, which could give up a type of the fixity of law in the rainbow, of all colors the most beautiful and ephemeral, of all forms the strongest, throwing across the clouds, still black with threatening, its perfect arch,—

> "A glorious thing that dauntless, deathless
> Sprang across them and stood steady."

THE RELATIONS OF CIVIL ENGINEERING TO OTHER BRANCHES OF SCIENCE.

BY JOHN ALEXANDER LOW WADDELL.

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THE topic set for this address is "The Relations of Civil Engineering to Other Branches of Science." In its broad sense civil engineering includes all branches of engineering except, perhaps, the military. This is its scope as recognized by two of the highest authorities, viz., the American Society of Civil Engineers and the Institution of Civil Engineers of Great Britain; for these two societies of *civil* engineers admit to their ranks members of all branches of engineering. It is evident, though, from a perusal of the Programme of this Congress that the Organizing Committee intended to use the term in a restricted sense, because it has arranged for addresses on mechanical, electrical, and mining engineering. But what are the proper restrictions of the term is, up to the present time, a matter of individual opinion, no authority having as yet attempted definitely to divide engineering work among the various

branches of the profession. To do so would, indeed, be a most difficult undertaking; for not only do all large constructions involve several branches of engineering, but also the profession is constantly being more minutely divided and subdivided. For instance, there are recognized to-day by the general public, if not formally by the profession, the specialties of architectural, bridge, chemical, electrical, harbor, highway, hydraulic, landscape, marine, mechanical, metallurgical, mining, municipal, railroad, and sanitary engineering, and possibly other divisions; and the end is not yet, for the tendency of modern times in all walks of life is to specialize.

Between Tredgold's broad definition of civil engineering, which includes substantially all the applied sciences that relate to construction, and the absurdly narrow definition which certain engineers have lately been endeavoring to establish during the course of a somewhat animated discussion, and which would confine civil engineering to dealing with stationary structures only, there must be some method of limitation that will recognize the modern tendency toward specialization without reducing the honored profession of civil engineering to a mere subdivision of applied mechanical science.

Without questioning in any way the correctness of the Tredgold definition, civil engineering will be assumed, for the purposes of this address, to include the design and construction of bridges; extensive and difficult foundations; tunneling; retaining-walls, sea-walls, and other heavy masonry; viaducts; wharves; piers; docks; river improvement; harbors and waterways; water-supply; sewerage; filtration; treatment of refuse; highway construction; canals; irrigation works; dams; geodetic work; surveying; railways (both steam and electric); gas-works; manufacturing plants; the general design and construction of plants for

the production of power (steam, electric, hydraulic, and gaseous); the general design and construction of cranes, cable-ways, breakers, and other mining structures; the heavier structural features of office buildings and other large buildings that carry heavy loads; the general problems of transportation, quarrying, and the handling of heavy materials; and all designing and construction of a similar nature.

In contradistinction, mechanical engineering should include the design and construction of steam engines, machine tools, locomotives, hoisting- and conveying-machinery, cranes of the usual types, rolling-mill machinery, blast-furnace machinery, and, in fact, all machinery which is designed for purely manufacturing purposes.

Electrical engineering should include all essentially electrical work, such as the designing, construction, and operation of telephone and telegraph lines; electric-light plants; dynamos; motors; switch-boards; wiring; electric devices of all kinds; transmission lines; cables (both marine and land); and storage batteries.

Mining engineering should include all underground mining work; means for handling the products of mines; roasting, smelting, milling, stamping, and concentrating of ores; drainage and ventilation of mines; disposal of mine refuse; and similar problems.

It is impracticable to draw hard-and-fast lines between the various branches of engineering, because, as before indicated, nearly all large constructions involve several specialties; consequently no specialist can confine his attention to a single line of work to the exclusion of all other lines. For instance, the bridge engineer encounters mechanical and electrical engineering problems in designing movable bridges; railroading in approaches to bridges; river improvement in the protection of piers and abutments; high-

way construction in the pavement of wagon bridges; architecture in the machinery houses of swing spans; hydraulic engineering in guarding bridges against fire; and chemistry and metallurgy in testing materials. The railroad engineer encounters architecture and structural engineering in depots, roundhouses, and other buildings; hydraulic problems in pumping-plants and bank protection; mechanical engineering in interlocking plants; and electrical engineering in repair-shop machinery. The mining engineer invades the field of mechanical and electrical engineering in his hoisting, ventilating, and transporting machinery; deals with civil engineering in his surveys; and encounters chemistry and metallurgy in testing ores. Similarly it might be shown that all branches of engineering overlap each other and are interdependent.

It was the general opinion among scientists not many years ago that engineering was neither a science nor a profession, but merely a trade or business; and even to-day there are a few learned men who hold to this notion—some of them, *mirabile dictu,* being engineers; but that such a view is entirely erroneous is now commonly conceded. He is an ill-informed man who to-day will deny that civil engineering has become one of the learned professions. Its advances in the last quarter of a century have been truly gigantic and unprecedented in the annals of professional development. It certainly can justly lay claim to being the veritable profession of progress; for the larger portion of the immense material advancement of the world during the last century is due primarily and preëminently to its engineers.

It must be confessed that half a century ago engineering was little better than a trade, but by degrees it advanced into an art, and to-day, in its higher branches at least, it is certainly a science and one of the principal sciences.

The sciences may be divided into two main groups, viz., "Pure Sciences" and "Applied Sciences."

The "Pure Sciences" include:

(1) Those sciences which deal with numbers and the three dimensions in space, the line, the surface, and the volume, or in other words "Mathematics."

(2) Those sciences which deal with inorganic matter, its origin, structure, metamorphoses, and properties; such as geology, petrology, chemistry, physics, mineralogy, geography, and astronomy.

(3) Those sciences which deal with the laws, structure, and life of organic matter; such as botany, zoölogy, entomology, anatomy, physiology, and anthropology.

(4) The social sciences; such as political economy, sociology, philosophy, history, psychology, politics, jurisprudence, education, and religion.

"Applied Sciences" include:

(1) Those which relate to the growth and health of organic matter; such as medicine, surgery, dentistry, hygiene, agriculture, floriculture, and horticulture.

(2) Those which deal with the transformation of forces and inorganic matter, viz., the various lines of engineering, —civil, mechanical, electrical, mining, marine, chemical, metallurgical, architectural, etc.

(3) Those which relate to economics; such as industrial organizations and manufactures, transportation, commerce, exchange, and insurance.

Some writers make no distinction between the terms "Political Economy" and "Economics," but in this address they are divided, the former relating to broad subjects of national importance, and the latter to minor matters and to some of the details of larger ones. For instance, currency, the national debt, banking, customs, taxation, and the subsidizing of industries pertain to "Political Econ-

omy," while economy of materials in designing and of cost of labor in construction, supplanting of hand-power by machinery, systematization of work of all kinds, adjustment of grades and curvature of railroads to traffic, and time- and labor-saving devices come under the head of "Economics."

The distinctions between the pure and the applied sciences are at times extremely difficult to draw, for one science often merges almost imperceptibly into one or more of the others.

The groups of pure sciences that have been enumerated may be termed:

The Mathematical Sciences,
The Physical Sciences,
The Physiological Sciences, and
The Social Sciences;

while the groups of applied sciences may be called:

The Organic Sciences,
The Constructive Sciences, and
The Economic Sciences.

In what follows the preceding nomenclature will be adopted.

The terming of engineering the "Constructive Science" is a happy conception, for engineering is truly and almost exclusively the science of construction. The functions of the engineer in all cases either are directly constructive or tend toward construction.

The engineer has ever had a due appreciation of all the sciences, imagination to see practical possibilities for the results of their findings, and the common-sense power of applying them to his own use.

Pure science (barring perhaps political economy) is not concerned with financial matters, and its devotees often look down with lofty disdain upon everything of a utili-

tarian nature, but engineering is certainly the science most directly concerned with the expenditure of money. The engineer is the practical man of the family of scientists. While he is sufficiently well informed to be able to go up into the clouds occasionally with his brethren, he is always judicious and comes to earth again. In all his thoughts, words, and acts he is primarily utilitarian. It is true that he bows down to the goddess of mathematics, but he always worships from afar. It is not to be denied that mathematics is the mainstay of engineering; nevertheless the true engineer pursues the subject only so far as it is of practical value, while the mathematician seeks new laws and further development of the science in the abstract. The engineer does not trouble himself to consider space of four dimensions, because there are too many things for him to do in the three-dimension space in which he lives. Non-Euclidian geometry is barred from his mind for a fuller understanding of the geometry which is of use to ordinary mankind. The mathematician demonstrates that the triangle is the sole polygonal figure which cannot be distorted, while the engineer, recognizing the correctness of the principle, adopts it as the fundamental, elementary form for his trusses. The mathematician endeavors to stretch his imagination so as to grasp the infinite, but the engineer limits his field of action to finite, tangible matters.

The geologist, purely studious, points out what he has deduced about the construction of the earth; but the engineer makes the mine pay.

The chemist discovers certain facts about the effects of different elements in alloys; but the engineer works out and specifies a new material for his structures. Again, the chemist learns something about the action of clay combined with carbonate of lime when water is added, and from this discovery the engineer determines a way to produce hydraulic cement.

The physicist evolves the theory of the expansive power of steam, and the engineer uses this knowledge in the development of the steam engine. Again, the physicist determines by both theory and experiment the laws governing the pressure exerted by liquids, and the engineer applies these laws to the construction of dams and ships.

The botanist with his microscope studies the form and construction of woods, while the engineer by experimentation devises means to preserve his timber.

The biologist points to bare facts that he has discovered, but the engineer grasps them and utilizes them for the purification of water-supplies.

In short, the aim of pure science is discovery, but the purpose of engineering is usefulness.

The delvers in the mysterious laboratories, the mathematical gymnasts, the scholars poring over musty tomes of knowledge, are not understood by the work-a-day world, nor do they understand it. But between stands the engineer with keen and sympathetic appreciation of the value of the work of the one and a ready understanding of the needs and requirements of the other; and by his power of adaptability he grasps the problems presented, takes from the investigators their abstract results, and transforms them into practical usefulness for the world.

The work of the engineer usually does not permit him to make very extensive researches or important scientific discoveries; nor is it often essential to-day for him to do so, as there are numerous investigators in all lines whose object is to deduce abstract scientific facts; nevertheless there comes a time occasionally in the career of every successful engineer when it is necessary for him to make investigations more or less abstract, although ultimately utilitarian; consequently it behooves engineers to keep in touch with the methods of scientific investigation, in order that they

may either perform desired experiments themselves, or instruct trained investigators how to perform them.

The engineer must be more or less a genius who invents and devises ways and means of applying all available resources to the uses of mankind. His motto is "utility," and his every thought and act must be to employ to the best advantage the materials and conditions at hand. To be able to accomplish this object he must be thoroughly familiar with all useful materials and their physical properties as determined by the investigations of the pure scientists.

Many well-known principles of science have lain unused for ages awaiting the practical application for which they were just suited. The power of steam was known long before the practical mind of Watt utilized it in the steam engine.

The engineer is probably an evolution of the artisan rather than of the early scientist. His work is becoming more scientific because of his relations and associations with the scientific world. These relations of the engineer to the sciences are of comparatively recent origin, and this fact accounts for the rapid development in the engineering and industrial world of the past half-century. The results of this association have been advantageous to both the engineer and the pure scientist. The demands of the engineers for new discoveries have acted as an incentive for greater effort on the part of the investigators. In many instances the engineer is years in advance of the pure scientist in these demands; but, on the other hand, there are, no doubt, many valuable scientific facts now available which will yet work wonders when the engineer perceives their practical utility.

The engineer develops much more fully the faculty of discernment than does the abstract scientist, he is less vis-

ionary and more practical, less exacting and more commercial.

It is essential to progress that large stores of scientific knowledge in the abstract be accumulated and recorded in advance by the pure scientists, so that as the engineer encounters the necessity for their use he can employ them to the best advantage. The engineer must be familiar with these stores of useful knowledge in order to know what is available. This forms the scientific side of the engineer's work. While he must know what has been done by investigators, it is not absolutely necessary that he know how to make all such researches for himself; although, as before stated, there are times in an engineer's practice when such knowledge will not come amiss.

All engineers are specializing more and more, each particular specialty becomes more closely allied with the sciences that most affect it; consequently, to insure the very best and most economic results in his work the engineer must keep in close touch with all of the scientific discoveries in his line.

The early engineers, owing to lack of scientific knowledge, took much greater chances in their constructions than is necessary for up-to-date, modern engineers. There is now no occasion for an engineer to make any hazardous experiments in his structures, because by careful study of scientific records he can render his results certain.

In future the relations between engineers and the pure scientists will be even closer than they are to-day, for as the problems confronted by the engineer become more complex and comprehensive the necessity for accurate knowledge will increase.

The technical training now given engineers involves a great deal of the purely scientific; and it is evident that this training should be so complete as to give them a comprehen-

sive knowledge of all the leading sciences that affiliate with engineering. There is no other profession that requires such a thorough knowledge of nature and her laws.

Of all the various divisions and subdivisions of the sciences hereinbefore enumerated and of those tabulated in the Organizing Committee's "Programme," the following only are associated at all closely with civil engineering:

Mathematics, Geology, Petrology, Chemistry, Physics, Mineralogy, Geography, Astronomy, Biology, Botany, Political Economy, Jurisprudence, Education, Economics.

Attention is called to the fact that this list contains a number of divisions from the four main groups of pure sciences, viz., the mathematical, physical, physiological, and social, and but one division (economics) from the three groups of applied sciences, viz., the organic, constructive, and economic. The reasons why so little attention is to be given to the relation between civil engineering and the applied sciences are, first, in respect to organic science, there is scarcely any relation worth mentioning between this science and civil engineering, and, second, because the interrelations between civil engineering and other divisions of constructive science have already been treated in this address.

Of all the pure sciences there is none so intimately connected with civil engineering as mathematics. It is not, as most laymen suppose, the whole essence of engineering, but it is the engineer's principal tool. Because technical students are drilled so thoroughly in mathematics and because so much stress is laid upon the study of calculus, it is commonly thought that the higher mathematics are employed constantly in an engineer's practice; but as a matter of fact, the only branches of mathematics that a constructing engineer employs regularly are arithmetic, geometry, algebra, and trigonometry. In some lines of work logarithms are

used often, and occasionally in establishing a formula the calculus is employed; but the engineer in active practice soon pretty nearly forgets what analytical geometry and calculus mean. As for applied mechanics, which, as the term is generaly understood, is a branch of mathematics (although it involves also physics and other sciences), the engineer once in a while has to take down his old text-books to look up some principle that he has encountered in his reading but has forgotten. Strictly speaking, though, engineers in their daily tasks utilize applied mechanics, almost without recognition; for stresses, moments, energy, moments of inertia, impact, momentum, radii of gyration, etc., are all conceptions of applied mechanics; and these are terms that the engineer employs constantly.

There are some branches of the higher mathematics of which as yet engineers have made no practical use, and prominent among these is quaternions. When it first appeared the conciseness of its reasoning and its numerous short-cuts to results gave promise of practical usefulness to engineers, but thus far the promise has not been fulfilled.

Notwithstanding the fact that the higher mathematics are of so little use to the practicing engineer, this is no reason why their study should be omitted from or even slighted in the technical schools; because when an engineer has need in his work for the higher mathematics he needs them badly; besides, the mental training that their study involves is almost a necessity for an engineer's professional success.

Geology (with its allied branch, or more strictly speaking subdivision, petrology) and civil engineering are closely allied. Civil engineers are by no means so well versed in this important science as they should be. This, perhaps, is due to the fact that the instruction given on geology in technical schools is mainly from books, hence

most graduates find difficulty in naming properly the ordinary stones that they encounter, and are unable to prognosticate with reasonable assurance concerning what a proposed cutting contains.

Geology is important to the civil engineer in tunneling, railroading, foundations, mining, water-supply, and many other lines of work; consequently, he needs to receive at his technical school a thorough course in the subject given both by text-books and by field instruction.

A knowledge of petrology will enable the engineer to determine readily whether building-stone contains iron which will injure its appearance on exposure, or feldspar which will disintegrate rapidly under the action of the weather or of acids from manufacturing establishments.

Next to mathematics, physics is undoubtedly the science most essential to civil engineering. The physicist discovers and formulates the laws of nature, the engineer employs them in "directing the sources of power in nature for the use and convenience of man." The forces of gravitation, adhesion, and cohesion; the pressure, compressibility, and expansibility of fluids and gases; the laws of motion, curvilinear, rectilinear, accelerated, and retarded; momentum; work; energy; the transformation of energy; thermodynamics; electricity; the laws of wave-motion; the reflection, refraction, and transmission of light; and the mass of other data furnished by the physicist form a large portion of the first principles of civil engineering.

The function of applied mechanics is to establish the fundamental laws of physics in terms suitable for service, and to demonstrate their applicability to engineering construction.

Chemistry is a science that enters into closer relations with civil engineering than does any other science except mathematics and physics, and as the manufacture of the

materials of engineering approaches perfection the importance of chemistry to engineers increases. Within a comparatively short period the chemist has made it possible by analyzing and selecting the constituents to control the quality of cast-iron, cast-steel, rolled-steel, bronze, brass, nickel-steel, and other alloys. The engineer requires certain physical characteristics in his materials, and obtains them by limiting the chemical constituents in accord with data previously furnished by the chemist. The proper manufacture of cement requires the combined skill and knowledge of the chemist and the mechanical engineer.

In water-supply the chemist is called in to determine the character and amounts of the impurities in the water furnished or contemplated for use. The recent discovery that the introduction of about one part of sulphate of copper in a million parts of water will effectively dispose of the algæ, which have long given trouble, is a notable instance of the increasing interdependence of these two branches of science as is also the fact that the addition to water of a small amount of alum will precipitate the earthy matter held in suspension without leaving in it any appreciable trace of the reagent.

In the purification of water and sewage, in the selection of materials which will resist the action of acids and the elements, and in the manufacture of alloys to meet various requirements, a thorough knowledge of chemistry is essential.

A knowledge of mineralogy is requisite for a clear understanding of the nature of many materials of construction, but is otherwise of only general interest to civil engineers.

Geography in its broad sense is related to civil engineering in some of its lines, for instance, geodesy and surveying, but generally speaking there is not much connection between these two branches of science.

Astronomy is perhaps more nearly related to civil engineering than is geography, although it is so related in exactly the same lines, for the railroad engineer on a long survey must occasionally check the correctness of his alignment by observations of Polaris, and the coast surveyor locates points by observations of the heavenly bodies.

Biology is allied to civil engineering mainly through bacteriology as applied to potable water, the treatment of sewage to prevent contamination of streams, and the sanitation of the camps of surveying and construction parties. The treatment of sewage has been given much more thorough study abroad than in this country, but the importance of its bearing upon life in the large cities of America is becoming better understood; consequently the progressive sanitary engineer should possess a thorough knowledge of bacteriology. In important cases, such as an epidemic of typhoid fever, the specialist in bacteriology would undoubtedly be called in; but a large portion of the work of preventing or eradicating bacterial diseases will fall to the lot of the sanitary engineer.

Botany comes in touch with civil engineering mainly, if not solely, in the study of the various woods used in construction; although it is a fact that a very intimate knowledge of this pure science might enable a railroad engineer or surveyor to determine approximately the characters of soils from plants and trees growing upon them. A knowledge of botany is of no great value to the civil engineer, and much time is often wasted on its study in technical schools.

Political economy is a science that at first thought one would be likely to say is not at all allied to civil engineering; but if he did so, he would be mistaken, because political economy certainly includes the science of business and finance, and civil engineering is most assuredly a business

as well as a profession; besides, the leading engineers usually are either financiers themselves or advisers to financiers. Great enterprises are often evolved, studied, financed, and executed by engineers. How important it is then that they understand the principles of political economy, especially in its relation to engineering enterprises. It is only of late years that technical students have received much instruction in this branch of social science, and the ordinary technical school curriculum to-day certainly leaves much to be desired in respect to instruction in political economy.

Jurisprudence and civil engineering are closely allied, in that engineers of all lines must understand the laws of business and the restrictions that are likely to be placed upon their constructions by municipal, county, state, and federal laws. While most engineering schools carry in their lists of studies the "Laws of Business," very few of them devote anything like sufficient attention to this important branch of science.

Are the sciences of civil engineering and education in any way allied? Ay, that they are! and far more than most people think, for there is no profession that requires as much education as does civil engineering. Not only must the would-be engineer study the various pure and applied sciences and learn a great mass of technical facts; but he must also have in advance of all this instruction a broad, general education—the broader the better, provided that no time be wasted on useless studies, such as the dead languages.

The science of education is so important a subject for civil engineers that all members of the profession in North America, more especially those of high rank, ought to take the deepest interest in the development of engineering education, primarily by joining the special society organized for its promotion, and afterwards by devoting some of

their working time to aid this society in accomplishing its most praiseworthy objects.

The science of economics and that of civil engineering are, or ought to be, in the closest possible touch; for true economy in design and construction is one of the most important features of modern engineering. Every high-class engineer must be a true economist in all the professional work that he does, for unless one be such, it is impossible to-day for him to rise above mediocrity.

True economy in engineering consists in always designing and building structures, machines, and other constructions so that, while they will perform satisfactorily in every way all the functions for which they are required, the sum of their first cost and the equivalent capitalized cost for their maintenance, operation, and repairs shall be a minimum. The ordinary notion that the structure or machine which is least in first cost must be the most economical is a fallacy. In fact, in many cases, just the opposite is true, the structure or machine involving the largest first cost being often the cheapest.

Economics as a science should be taught thoroughly to the student in the technical school, then economy in all his early work should be drilled into him by his superiors during his novitiate in the profession, so that when he reaches the stage where he designs and builds independently, his constructions will invariably be models of true economy.

It has been stated that the relations between civil engineering and many of the pure sciences are very intimate, that the various branches of engineering, although becoming constantly more and more specialized, are so interdependent and so closely connected that they cannot be separated in important constructions, that the more data the pure scientists furnish the engineers, the better it is for both parties, and that a broad, general knowledge of many of

the sciences, both pure and applied, is essential to great success in the engineering profession.

Such being the case, the question arises as to what can be done to foster a still closer affiliation between engineering and the other sciences, and how engineers of all branches and the pure scientists can best be brought into more intimate relations, in order to advance the development of the pure sciences, and thus benefit the entire world by increasing the knowledge and efficiency of its engineers.

One of the most effective means is to encourage the creation of such congresses as the one that is now being held, and to organize them and arrange their various meetings so as to secure the greatest possible beneficial results.

Another is for such societies as the American Association for the Advancement of Science and the Society for the Promotion of Engineering Education to take into their membership engineers of good standing, and induce them to share the labors and responsibilities of the other members.

Conversely, the various technical societies should associate with them by admission to some dignified grade (other, perhaps, than that of full member) pure scientists of high rank and specialists in other branches of constructive science, and should do their best to interest such gentlemen in the societies' objects and development.

A self-evident and most effective method of accomplishing the desired result is to improve the courses of study in the technical schools in every possible way; for instance, by bringing prominent scientists and engineers to lecture to the students and to tell them just how scientific and professional work of importance is being done throughout the world, by stimulating their ambition to rise in their chosen professions, by teaching them to love their work instead of looking upon it as a necessary evil, and by offering prizes

and distinctions for the evidence of superior and effective mental effort on the part of both students and practicing engineers.

There has lately been advanced an idea which, if followed out, would aid the development of engineering more effectually than any other possible method, and incidentally it would bring into close contact scientists in all branches related directly or indirectly to engineering. It is the establishment of a great post-graduate school of engineering in which should be taught in every branch of the profession the most advanced subjects of all existing knowledge that is of real, practical value, the instructors being chosen mainly from the leading engineers in each specialty, regardless of the cost of their services. Such specialists would, of course, be expected to give to this teaching only a few weeks per annum, and a corps of regular professors and instructors, who would devote their entire time and energies to the interests of the school, would be required. These professors and instructors should be the best that the country possesses, and the inducements of salary and facilities for investigation that are provided should be such that no technical instructor could afford to refuse an offer of a professorship in this school.

Every modern apparatus needed for either instruction or original investigation should be furnished; and arrangements should be made for providing means to carry out all important technical investigations.

It should be the duty of the regular faculty to make a special study of engineering literature for the benefit of the profession; to prepare annual indices thereof; to put into book form the gist of all technical writings in the *Transactions* of the various engineering societies and in the technical press that are worthy of being preserved and recorded in this way, so that students and engineers shall

be able to search in books for all the data they need instead of in the back files of periodicals; to translate or assist in the translation of all engineering books in foreign languages, which, in the opinion of competent experts, would prove useful to engineers or to the students of the school; and to edit and publish a periodical for the recording of the results of all investigations of value made under the auspices of the institution.

In respect to what might be accomplished by such a postgraduate school of engineering the following quotation is made from the pamphlet containing the address in which the project was advanced:[1]

"The advantages to be gained by attendance at such a post-graduate school as the one advocated are almost beyond expression. A degree from such a school would always insure rapid success for its recipient. Possibly for two or three years after taking it a young engineer would have less earning capacity than his classmates of equal ability from the lower technical school, who had gone directly into actual practice. However, in five years he certainly would have surpassed them, and in less than ten years he would be a recognized authority, while the majority of the others would be forming the rank and file of the profession, with none of them approaching at all closely in reputation the more highly educated engineer.

"But if the advantages of the proposed school to the individual are so great, how much greater would be its advantages to the engineering profession and to the entire nation. After a few years of its existence there would be scattered throughout the country a number of engineers more highly trained in the arts and sciences than any technical men who have ever lived; and it certainly would not

[1] Higher Education for Civil Engineers: an Address to the Engineering Society of the University of Nebraska, April 8, 1904, by J. A. L. Waddell, D.Sc., LL.D.

take long to make apparent the impress of their individuality and knowledge upon the development of civil engineering in all its branches, with a resulting betterment to all kinds of constructions and the evolution of many new and important types.

"When one considers that the true progress of the entire civilized world is due almost entirely to the work of its engineers, the importance of providing the engineering profession with the highest possible education in both theoretical and practical lines cannot be exaggerated.

"What greater or more worthy use for his accumulated wealth could an American multi-millionaire conceive than the endowment and establishment of a post-graduate school of civil engineering."

Another extremely practical and effective means for affiliating civil engineering and the other sciences is for engineers and professors of both pure science and technics to establish the custom of associating themselves for the purpose of solving problems that occur in the engineers' practice. Funds should be made available by millionaires and the richer institutions of learning for the prosecution of such investigations.

Another possible (but in the past not always a successful) method is the appointment by technical societies of special committees to investigate important questions. The main trouble experienced by such committees has been the lack of funds for carrying out the necessary investigations, and the fact that in nearly every case the members of the committees were unpaid except by the possible honor and glory resulting from a satisfactory conclusion of their work.

Finally, an ideal but still practicable means is the evolution of a high standard of professional ethics, applicable to all branches of engineering, and governing the relations of

engineers to each other, to their fellow workers in the allied sciences, and to mankind in general.

As an example of what may be accomplished by an alliance of engineering and the pure sciences, the construction of the proposed Panama Canal might be mentioned. Some years ago the French attempted to build this waterway and failed, largely on account of the deadly fevers which attacked the workmen. It is said that at times the annual death-rate on the work ran as high as six hundred per thousand. Since the efforts of the French on the project practically ceased, the sciences of medicine and biology have discovered how to combat with good chances for success the fatal malarial and yellow fevers, as was instanced by the success of the Americans in dealing with these scourges in the city of Havana after the conclusion of the Spanish-American war.

The success of the American engineers in consummating the great enterprise of excavating a navigable channel between the Atlantic and Pacific oceans (and concerning their ultimate success there is almost no reasonable doubt) will depend largely upon the assistance they receive from medical science and its allied sciences, such as hygiene, bacteriology, and chemistry.

Geological science will also play an important part in the design and building of many portions of this great work, for a comprehensive and correct knowledge of the geology of the Isthmus will prevent the making of many costly mistakes, similar to those that resulted from the last attempt to connect the two oceans.

Again, the handling of this vast enterprise will involve from start to finish and to an eminent degree the science of economics. That this science will be utilized to the utmost throughout the entire work is assured by the character and professional reputation of both the Chief Engineer and the members of the Commission.

Notwithstanding, though, the great precautions and high hopes for a speedy and fortunate conclusion of the enterprise with which all concerned are starting out, many unanticipated difficulties are very certain to be encountered, and many valuable lives are likely to be expended on the Isthmus before the first steamer passes through the completed canal. Engineering work in tropical countries always costs much more and takes much longer to accomplish than is at first anticipated; and disease, in spite of all precautions, is very certain to demand and receive its toll from those who rashly and fearlessly face it on construction works in the *tierra caliente*. But with American engineers in charge, and with the finances of the American Government behind the project, success is practically assured in advance.

What the future of civil engineering is to be, who can say? If it continues to advance as of late by almost geometrical progression, the mind of man can hardly conceive what it will become in fifty years more. Every valuable scientific discovery is certainly going to be grasped quickly by the engineers and put to practical use by them for the benefit of mankind, and is is only by their close association with the pure scientists that the greatest possible development of the world can be attained.

THE RELATIONS OF MECHANICAL ENGINEERING TO OTHER BRANCHES OF ENGINEERING.

BY ALBERT WILLIAM SMITH.

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THE problem of educating young men to take up the world's work in engineering is a continually changing one. Engineering continually increases in scope and complexity and keeps demanding better trained and wiser men for the solution of its problems. What are the technical schools to do to meet this demand?

Engineering is not an exact science; the sum of knowledge on which it rests is too meagre for exactness. Many of the factors of an engineering problem are susceptible of exact determination from known facts and mathematical deductions; others can be approximately estimated; while others still are elusive and prone to hide themselves, often successfully. Many a man has based an engineering work involving the expenditure of large sums of money upon an analysis in which one factor has eluded the "round-up." Then when money was spent, when the idea was in cold metal, this little cold-blooded factor came out, pointed a condemning finger at the man and said: "This won't do, you forgot me!"

I wish to make a slightly adapted quotation: "The mathematician in solving a problem takes into account all the factors that appear; the engineer must consider all the

factors there are." The work of the engineer must not fail, or destruction of human life and property results, and he is criminally responsible. He must consider all the factors there are!

As the sum of knowledge grows it becomes quite complete in certain divisions of engineering work. Then factors of safety are reduced, standards are designed, and the work may be done by any one who can learn a routine and can follow it repeatedly with accuracy. But the real engineer has nothing further to do with it, unless new applications are demanded.

But most engineering work reaches into unexplored or partially explored fields, and in such cases the last appeal is to the judgment of some man. In other words the real engineer is a man of trained judgment. It is impossible to teach any general method for the solution of engineering problems. No two are alike; the modifying factors are so many that the possible number of combinations is indefinitely great and the same combination seldom recurs. A man's judgment must be trained so that he can take any combination and reach a good solution; not necessarily the best solution, for there may be many good solutions differing only slightly in results.

Judgment for its training must draw from many sources. There must be the understanding of the mathematical basis of all engineering; a knowledge of inorganic nature's laws and of the qualities of engineering materials and of constructive principles; and all this the schools ought to supply. But there must also be the experience which comes from being "up against the real thing" with no authority at hand to appeal to—when there is just the man and the problem and the necessity for a result. This is the kind of experience which tries men's souls and makes engineers —or failures. It cannot be supplied by the schools.

ARCHIMEDES.

Hand-painted Photogravure from the Painting by Niccolo Barabino.

The most important services of Archimedes were rendered to pure Geometry, but his popular fame rests chiefly on his application of mathematical theory to mechanics. He invented the water-screw and discovered the principle of the lever. Concerning the latter the famous saying is attributed to him: "Give me where I may stand and I will move the world." He first established the truth that a body plunged in a fluid loses as much of its weight as is equal to the weight of an equal volume of fluid. This is known as the "Principle of Archimedes," and is one of the most important discoveries in the science of Hydrostatics. It was by this law that he determined how much alloy the goldsmith, whom King Hiero had commissioned to make a crown of pure gold, had fraudulently mixed with the metal. The solution of the problem suggested itself to Archimedes as he was entering the bath, and he is reported to have been so overjoyed that he ran through the streets without waiting to dress, exclaiming, "Eureka! Eureka!" (I have found it!). He was killed at the age of seventy-five, during the capture of Syracuse by Marcellus in 287 B.C. The original painting of Archimedes by Niccolo Barabino is in the Orsini palace, Genoa.

There has always been a gap between the technical schools and the practice of engineering. Thirty years ago when practice was simpler and the schools cruder, this gap was wide. In those days engineering firms and manufacturers did not seek to employ technical graduates; they said: "We have tried them and they always try to shift a belt on the wrong side of a pulley; we prefer to train up our own men." That this gap has narrowed somewhat is shown by the fact that men in authority in three prominent engineering and manufacturing firms came to Cornell last June to meet members of the graduating class with a view to engaging young men for their work, and this same thing happens at other schools. But still there is the gap; the graduate must still unlearn some things that have been improperly taught, and must learn other things that have not been taught at all. There must of course always be a period of readjustment because the conditions in practice and in the schools can never—from the nature of the case —be the same.

To meet the demand therefore the schools must cease to teach wrong things, and must teach right things.

The development of engineering, with the accompanying development of the engineering schools, has been a very interesting process. Out of the "chalk age" has come the orderly present practice. In the chalk age a man would go into his shop with an idea in his head and a piece of chalk in his hand; he would clear off a place on the workbench and call up his best man. He would sketch and explain and when asked about dimensions would take out his two-foot rule and slide his thumb along it till he reached the right place and chalk it down. Then the best man would look in the scrap-heap for available parts; would interview the pattern-maker and the blacksmith; and later there would be a machine. This machine would be tested;

parts that failed would be replaced by stronger ones, motion ratios would be adjusted, and finally the machine would perform its function, all honor to the fine men who did this work. But this process of machine evolution was tedious and expensive, and the chalk man often wished he could figure out dimensions because he saw profit in getting things right the first time. It was in response to many such wishes that the technical schools appeared. But they did not spring full-armed into being. Like other earthly things they have developed by orderly growth. The law of survival of the fittest operated as in organic evolution; unfit things have fallen away and have been replaced by fitter ones, while much that was good has survived. From the first it was clear that an engineer should understand the laws of inorganic nature and the relations of numbers, and hence physics and chemistry and mathematics were included in the early courses. But the use of shops for the training of engineers does not seem to have been grasped, for students in most cases were simply taught handicraft. One exception was the shop in which Professor Sweet taught not only skill with tools but also principles of construction, together with the highest ideals in machine design. But Professor Sweet is such a man as comes but once in a generation or two.

Many of the technical courses were grafted on the existing college courses and an attempt was made to combine a liberal and a technical training. It does not need to be stated that these schools were inadequate even in the simpler state of engineering; and yet—out of these schools came many of the men who have helped to bring engineering to its present advanced state. But that was because they had power to bring what they had learned into action, to supplement it by wisdom gained in practice; in other words, to train their judgment till they became real engineers.

In contrast to this is the present state of the technical schools. Engineering has developed steadily and the schools have tried to meet its demands; not with perfect success, but still successfully.

One of the difficulties about technical schools is that the teacher by the very fact of teaching is put out of touch with his profession; and the profession advances so rapidly that in a few years he is side-tracked. He teaches engineering as he knows it; but that is not as it is.

Some teachers who are fortunately placed combine consulting work with teaching, and if a nice balance can be maintained this must give good results. There is always, however, a temptation to give too much attention to the consulting work with its strenuous demands and to slight the teaching.

It would seem that the ideal way is to spend alternating periods of a few years in teaching and practical work. This has been done in several cases on personal initiative with good results; and in at least one institution it now has the approval of trustees, president, and faculty.

If a man had just spent three years in advanced practice in engineering what would he find to criticise in any one of the many good modern American technical schools?

Let us consider this briefly in detail.

Mathematics. The devotee of pure mathematics delights in abstract processes. We have all heard of the toast offered at a banquet which concluded a congress of mathematicians: "Here's to Higher Mathematics, may she never be degraded to any human use." This was only half-meant.

I know a man who says that a mathematical question loses all interest for him as soon as it proves to have a practical application. His feeling is right; the work of his kind has been of infinite service to humanity, but he is not of the stuff of which engineers are made.

The mathematical subjects in technical schools have always been taught to engineers by mathematicians and they have very naturally presented and emphasized the things that had greatest interest for them. These are not usually the things of most use to the engineer. In some cases, no doubt, such teachers have resented suggestions as to their teaching; but in most cases I believe they receive suggestions gladly and are anxious to do all in their power to make their service most efficient. I believe we are to blame who have allowed suggestions to be lacking. He who has spent any considerable time in modern mechanical engineering work knows that for most of the figuring only a knowledge of the elements of the mathematical subjects given in the technical courses is needed. But it must be a *working knowledge.* Occasionally a problem arises requiring more advanced knowledge for its solution. Why not then apply to what Mr. A. P. Trotter in a recent paper calls a "tame mathematician" for a solution which can be applied by the engineer. If a man can be an expert mathematician and an able engineer also, it is a fine thing; but most men cannot because of the time-limit to life.

It would seem that the trouble with the teaching of mathematics for engineers is that it goes too far and not deep enough. It is a working knowledge of elements that the engineer needs. Why not drill him till he can use the elements as he uses arithmetical processes, and leave the advanced work to the pure mathematician?

Shops. The object of a shop-course in a trade-school is to teach handicraft to one whose life-work is to be in the shop. The object of a shop-course in an engineering school is to give an understanding of principles of machine construction to one who needs such understanding to be a successful engineer. Obviously the method should be different in the two cases. In the first case it is of great im-

portance for the student to chip and file an exercise-piece so that it exactly fulfills the specifications; in the second case it is of very little importance.

A student cannot learn four trades working six or nine hours a week for nine months during each of three years; but he can learn in that time—if properly taught—much of machine construction which will help to make him a better engineer.

In the machine-shop all exercises that are for the training of the hand alone should be dropped and the student should learn the operation of every machine tool; he should be held to put each to its maximum safe output, so that he may grasp something of the meaning of economic production. He should be taught the methods of producing duplicate parts in large numbers at low cost. He should learn something of the shop organization and arrangement for minimum cost for handling; he should learn something of shop lighting and sanitation and its bearing on the cost of product; he should learn something of the methods of reward by which workmen are led to increase the shop output and their own incomes; he should learn about accurate and simple cost accounting and its economic results.

In the pattern-shop the making of ornamental vases and inlaid boxes should be excluded and the student should learn the best methods of pattern-making, and to distinguish between the allowable expenses of a pattern made for one casting and a pattern made for many castings; he should be shown all the short cuts that save labor in the pattern-shop and the foundry.

the foundry art-casting should cease and the student should learn the methods of green-sand, loam, and sweep-work, either by the actual execution or by explanation with models; he should do snap-flask work and should see moulding-machines operated; he should learn economic

methods of handling raw material and the product in large foundries; he should know how to make charge mixtures for different results and should study cupola and air-furnace operation for best product.

In the smith-shop artistic forging should be excluded and the student should learn not only simple forging, tool-dressing, and heat-treatment of steel; but he should also be introduced in the production of duplicate parts by drop-presses, and in the methods used for the production and annealing of large forgings.

This is not too high a standard for the shops of an engineering school; its realization will increase the value of the schools to practice and hence it will come. Obviously it involves great changes in existing methods. Shop-talks and class-room work must supplement actual work because so many principles are involved, and the actual work must be greatly modified. Already many of the schools have made a start in this direction.

Drawing and Design. In drawing all art-work should be excluded, and the student should learn to make neat and clear-dimensioned sketches and accurate, well-executed working drawings with good plain lettering.

In machine design the theory has long been well taught; but the modifications of design in response to the demands of practical every-day considerations have usually been neglected.

Experimental Work. The prime function of the undergraduate mechanical laboratory is to teach men to test the efficiency of machines, the secondary function is to afford opportunity for research. Many will object to this order because research is undoubtedly the higher work. For a post-graduate laboratory the order would be reversed; but for an undergraduate the thing of first importance is to learn methods of testing. If in addition to that he is able

to catch something of the investigator's spirit it is fortunate; but in most cases it will be but little; there isn't time. Moreover, the investigator and the engineer belong to different classes.

The engineer is he who conceives and materializes ideas that help humanity harness nature for its use. The investigator is he who extends the field of knowledge. This is not an absolute division, for many engineers find out lacking facts for their own use; and many investigators apply the facts they have determined; but in general the classification holds.

Once in a while there comes a student with the investigator's spirit; he is born to add to human knowledge. He is to be cherished and encouraged; if he shows a tendency toward engineering work, the brakes should be applied. The world has many engineers and few investigators, and the few cannot be spared.

The mechanical laboratory, although a comparatively recent addition to the technical courses, is very efficient in most of the schools. This is probably partly due to the fact that the inducement for teachers to keep in touch with practice is greater through consulting work than in the other departments. The criticism of the man just out of practice upon the mechanical laboratory would probably be that things are arranged too conveniently. A machine or a series of machines is made ready for operation, and the student makes certain observations from which he deduces results. In some cases he is not even allowed the responsibility of operation. In practical testing it is the getting ready that needs the engineer's best ingenuity and judgment and effort.

Steam Engineering. The tendency in this work has been too much to go far into theoretical thermo-dynamics. This is usually "over the heads" of the average under-

graduates. What the engineer needs is a working knowledge. The thermo-dynamic theory which suffices for this is not difficult, but it needs to be thoroughly understood. Again it is better to go deeper and not so far. Also the economic part of power development should be emphasized. It is not so much producing a maximum result per pound of steam as producing a maximum result per dollar cost.

These are criticisms in detail. What would be the criticism of the course as a whole—of the spirit of the place? In general it would probably be that the school needs to "get in line" with practice. The student coming out should not need to turn even through a small angle but should go straight on. Some details may illustrate:

Engineering work is done because it is paid for, and no solution is right which ignores the money factor. In the operation of any mechanical engineering installation, there is cost of labor; cost of supplies, including energy; cost due to depreciation; cost due to interest on first cost; cost of repairs; cost of probable delays; cost of taxation and insurance.

There may be many combinations of machines and apparatus that would give the required result, and each combination might vary all cost items. The engineer must determine the combination that would give the least sum of costs. It is believed that the schools are apt to consider economy of elements rather than of aggregates, and to neglect variations due to local conditions. This is not in line with practice.

Another thing that is not sufficiently emphasized is the judging of results by their reasonableness. I quote from a recent address to the graduating class of Stevens Institute by Mr. Walter C. Kerr: "This again is a thing which each man does for himself in his own best way, and its

essence consists in asking one's self whether the thing is reasonable. It is a great check upon error. It applies equally to nearly everything of which engineering is composed. It is the power of the human mind, after performing in more or less systematic and conventional ways, to stand off and look at results and ask one's self whether they are reasonable. One man will figure that certain material weighs two hundred tons, and believe it. Another will say that there is something wrong in that, for it all came in two cars."

The engineer in practice has to check results in this way because errors are costly in money and reputation; but in the school where ideas are not materialized the result of errors is less serious. The consequence is that it is customary to assume that a result is right because it has been figured. To use another illustration: One man may get a result by using seven-place logarithms and may say that it must be right because of the seven places. But another may check it through with a slide-rule and show a large error in the second figure of the result. After working out in detail, the whole problem should be looked at broadly for reasonableness. The schools should lead the student in this direction to line up with practice.

These are probable criticisms of a man fresh from practice. Every practicing engineer will, I think, recognize their reasonableness.

Who then are the men to work out the changes? The men with teaching capacity fresh from practice; and so again we come to see the desirability of alternating teaching and practical work.

Another difficulty is the present time-limit of the technical course. With engineering development has come the demand that the engineer should have broader training. The course was made to cover four years at first, and that

served for the early days; but now for years we have—so to speak—been blowing steam into a closed vessel from a high-pressure source; the result is too high pressure. Students are worked too hard and as a result cannot do the best work of which they are capable. It takes time for ideas to soak into the human brain. The solution is to increase the course to five years. The objection usually made is that students cannot afford the time and expense. But is this true? I know a man who spent ten years after entering college before he began the practice of medicine; four years in college, four years in the medical school, and two years in hospital work. This may be an extreme case, but this is the kind of a physician I would like to call in case of serious illness. Suppose the student leaves the technical school at the age of twenty-four. He may reasonably look forward to thirty-six or more years in the practice of his profession. If an additional year's study can increase the efficiency of each one of these years, is it not worth while? The increase in efficiency is not due alone to the additional year's work. The stress is reduced, and the development is more normal. Moreover, the danger of mental overstrain is reduced. The five-year course also would give opportunity for the introduction of outside work that would increase the engineer's power: elementary economics and transportation problems; elementary law and contracts; with a great deal more English composition and theme-writing.

The student will say that his father will not give him five years at the university. How about his brothers and friends who study law or medicine? We have only to get used to the idea. I believe the five-year course will come within the next five years.

In this same connection is another point. An engineer's success is increasingly dependent on his ability to meet men

of refinement and culture on their own plane. Obviously there is no time in a technical course for culture studies. For fifteen or more years there has been a tendency for a few men who have completed an arts course to take two or more years in engineering. This is a tendency to be encouraged, for it makes for increased power and efficiency in engineering. We ought to get into the habit of thinking of the technical school as a professional school to be entered only on the completion of the broader general course.

There is another criticism which has come to me many times from men in different grades of practice. The technical schools are organized so that a young man who has passed regularly through the public-school system finds entrance easy; while maturer men whose schooling has been irregular, but who have had several years of practical work in lines connected with engineering, find entrance difficult. Yet the latter class are apt to have greater capacity for becoming engineers. It seems certainly necessary to require that all candidates shall have the mathematical preparation. It is impossible to build without a foundation. But any earnest man with engineering capacity can get this preparation. It is other subjects that give trouble. If a man has spent several years in a shop or drafting-room, or at some other work directly connected with engineering, he certainly has increased his understanding of what engineering training should be; he has usually very much greater earnestness for study than the young man from the high school. In other words his work has been effective preparation for a technical course. There should not be any difficulty in giving value to such work toward entrance.

This problem may be solved as follows: Make the mathematical and English requirements rigid. Let the

other requirements stand as at present, but add to them shop-work, drawing, and such other subjects as may be judged to give equivalent training. Let a certain number of these subjects be required with free election. This plan is now in successful operation at Stanford University.

Some desirable men (I have known many of this class) might still be unable to enter. If they can offer the required mathematics, they may be admitted as special students. This would bar them from taking degrees, and this might seem a hardship if degrees are really of any value. This difficulty has been overcome at Stanford University by allowing a man who has entered as a special student to graduate by making a total of one hundred and fifty hours; that is by taking an extra year's work. This is of course simply making a man with defective entrance training take a five years' course for a degree.

After the technical school has done its full duty by a young man his education is only begun; he must spend years in contact with practice before he can attain that ripeness of judgment which will enable him to say of engineering schemes, this is right and that is wrong; before he can reach his full power as an engineer.

THE RELATION OF MINING ENGINEERING TO OTHER FIELDS

BY ROBERT HALLOWELL RICHARDS

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THE two papers of this Section appear to call for discussions more or less educational in their intent. The first paper to draw the picture of the various calls the mine makes upon its officers, leading up through the development of the business and finally reaching as a climax the educational requirements to fit the man for the place, deals more particularly with the man. The second, to review the past development, draw the picture of the present, and indicate the lines of progress that are most needed in the near future, deals more particularly with things.

I will begin my story by attempting to show how universally the work of the mining engineer reaches the interests of all. I will then trace from early beginnings the development from the primitive chance find of attractive mineral specimens to the modern, fully equipped mine. I will show how the mine not only supplies wants of all classes but calls upon many lines to respond by contributing to mine development. And, finally, will indicate the educational lines which are developed to bring men to as good an understanding as possible of how to get the most effective results in mining with the least expenditure of material and effort.

The province of the mining engineer may be defined as comprising all the duties and abilities that a mining engineer may be called upon to perform or possess, the end point of which is the extraction of valuable minerals and placing them on the market for the service of man. He brings from the ground into active use values which previously lay dormant and unknown to the uninitiated. He builds, out of apparent nothingness, things which eventually make for use and beauty in the service of men. He has, therefore, wide ethical and philosophical relations with the development of the human race.

Development of the Mining Engineer

Looking back through the eye of the imagination to prehistoric times, we may form a conception of an order of advance in things mining. The primitive man picked up colored stones, bored holes in them, and wore them as amulets for decorative, religious, or medicinal reasons. He found the precious stones and prized them for their decorative effect. He found the gold in nuggets, and later, that he could polish, flatten, and shape it, and made a beginning in the metal manufacturing art.

Gold and precious stones at a very early date must have risen in value and begun to be property, and also begun a career as a medium of exchange. A complete mining plant, at this time, may have been an area of land with ore specimens scattered on the surface of the ground and buried in the surface soil, with a few men digging with pointed sticks and moving the soil with rude wooden shovels. The existence of ownership in the soil and mineral may have developed later.

Stimulated by mineral discoveries, the miner made efforts to define, identify, and name his mineral species and so gave a beginning to the science of mineralogy; and his

efforts to establish rules of occurrence of his valuable minerals did the same for geology.

The primitive Asiatic at an early date found the effect of fire on minerals and picked up lead, copper, or iron in the ashes of his camp-fires. Cornwall tin was found in the same way.

The primitive metallurgist then experimented with his fires and got silver by burning up his lead, and bronze by alloying copper and tin.

The possibilities fascinated him, the getting stimulated the desire to get, and the ingenuity to fashion the tools to get with. In fact, the metallurgist has done much to stimulate the development of the chemist. There came to be a systematic use of fires for roasting ore, reverberatories for desulphurizing ore, crucibles for melting, cupels for purifying silver, hearths and shaft-furnaces for smelting.

The miner, pushed by his metallurgical partner, soon got to the end of the loose ore lying on the surface and began breaking it from the ledges with his stone hammers. He found that by heating the ore and quenching it with water it would crumble more easily. In fact, this was probably the chief method of mining for many centuries.

A mine at this period may have been a pit or trench twenty feet deep, more or less, from which the ore and water were carried out on men's backs, using a tree with stubs or branches for a ladder.

In time the metallurgist found that by manipulating his iron in connection with carbon he could harden it and that the hardness was greatly augmented by quenching it in water. He had made the discovery of steel and of tempering.

The miner asked for a better hammer and got one of steel and with it the "point" which by blows of the hammer chips and severs the ore from the ledge. The hammer

and point, "Schlegel und Eisen," must have been the standard mining tools for many centuries.

The primitive American mined copper at least 500 years before the discovery of this country by Europeans (Egleston). This is indicated by counting the rings in tree-trunks growing in their old workings. They mined the copper with stone hammers, heating the rock with fire to make it more friable. They mined to a depth of twenty or thirty feet, but rarely went underground; used wooden shovels to move the rock and wooden bowls and bark troughs to dispose of the water. They did not want and could not use pieces of copper larger than a few pounds, which they took as they found them, beat out cold into shapes, leaving the silver attached to the copper. They apparently had no knowledge of concentration or of smelting. They used the copper for tools of the household, of the shop, of the chase, and of war, as well as for decorative purposes.

The making of iron tools enabled the miner to penetrate into the ground. He devised ropes, buckets, and a rude windlass for lifting out ore and water. His roof and walls of rock began to fall in on him and it was necessary to bring in timber props and to leave pillars of ore to hold the walls apart.

About this time the horse-windlass and a better quality of rope must have been designed for hoisting from greater depths. Mines at this time may have reached a depth of hundreds of feet with tunnels and galleries though small in size, yet cut out with a care and finish almost like that of the stonemason's work on public buildings. Such tunnels of three hundred years ago can be seen to-day in the German mines.

The metallurgist asked for cleaner ore, free from earthy and siliceous impurities which hindered or prevented his

smelting operations; to effect this, the crude stamp for crushing, and the sweeping buddle for concentrating ores were developed.

As to the periods when the mineralogist, the geologist, and the chemist became separate professions, investigating everything in their lines and contributing from their stores of knowledge to the benefit of the miner, I will not discuss. But the time has never yet been reached when the miner could afford not to have a good working knowledge of those subjects.

The next great step was the use of drill and blasting powder (A. D. 1620). The slow, tedious chipping was replaced by the more rapid boring and blasting out of rock masses, and the speed of mining increased immensely.

A. D. 1776, the steam engine came to the help of the miner. The pumping engine came first, for removing water, and then the hoisting engine.

About A. D. 1840 the locomotive was invented and used for hauling coal and ore.

We sometimes think of all engineering depending on or pertaining to the steam engine, whereas the true engineer is a man who must adapt means to ends, whatever they may be and whether he ever did or did not know of them before. He can use precedent as far as it will go, and must fill in the rest from his brain. He may have to harness up a waterfall on the side of a mountain, bring down the water in a great pipe, and level gravel hills with a water jet more powerful than those used by our city fire departments. Or he may have to use the water to compress air and convey it in pipes to his mine and use it there to drive his powerful hoisting and pumping machinery and his power drills for drilling the rock.

In 1860 nitro-glycerine was introduced as a powerful blasting material, adding to the speed and economy of the work of excavation.

The miner, by his needs of prime movers, transmitting machinery, transporting machinery, and use of water, has contributed much to the development of the mechanical engineer and to a less degree to the railroad and hydraulic engineer.

The miner and the agriculturist really take shares in this development. They are both fundamental callings, taking the good things from the ground. The farmer has probably helped more in the development of the railroad, while the miner's field has given him a greater hand in developing power machinery and hydraulics.

Later these all became independent professions, and having made great advances in their studies they now in their turn contribute advanced ideas to the benefit of the miner.

But here again no mining engineer can afford to be without a good working knowledge of mechanical engineering, constructive engineering, hydraulic engineering, or railroad engineering.

This brings us to the great mines of to-day, and if we draw a few illustrations from the Calumet and Hecla Mine of Lake Superior, it will, perhaps, serve as well as any.

This represents both the primitive and the most modern things in mining. It was discovered by a prehistoric pit evidently worked by a race of advanced intelligence before the Europeans reached this country and it is now equipped with the finest mining machinery in the world. This mine is opened up by some fifteen shafts, more or less, on the slope of the deposit which are about 400 feet apart. The longest shaft is opened about 8000 feet down the slope. A vertical shaft nearly a mile deep connects with this below. Every one hundred feet, going down, there is a level or horizontal tunnel driven along the deposit either way, and these 100 by 400 feet blocks of copper-bearing rock are worked out by drilling and blasting with dynamite. The

roof is temporarily supported by carefully designed timbering which holds up the roof until the rock is all worked out, and then gradually crushes, letting the roof fall in. Every one of the levels has been carefully surveyed so they will properly connect with each other and the ends will not go beyond the boundary-lines, and they are supplied with a railroad track and cars. Every shaft has been surveyed, supplied with a track for the hoisting-skip and a hoisting-rope, at the top of the shaft is a rock house with two immense rock breakers, two great sheaves for turning the hoisting rope and a hoisting engine powerful enough to lift at great speed the rope skip and copper rock, weighing many tons, to the surface. Beneath the breakers is a great rock bin and tracks for shipping the rock down to the mills at Lake Linden, five miles away.

Several great air compressors furnish air for the rock drills operated by 3000 miners, more or less, producing 5000 tons or more of copper rock per day.

The mine has waterworks bringing the pure water of Lake Superior up to 600 feet in height, four miles in distance, to supply the boilers and also the company's houses.

A huge revolving fan uses one shaft for ventilating the many miles of shafts, levels, and stopes, giving the miners fresh air and removing the powder smoke.

The mine has machine-shop, foundry, blacksmith-shop, and carpenter-shop, capable of doing the finest work on large or small scale.

Going to the mills at the Lake, we find two large mills with about eleven steam stamps each, 22 in all. Each of these stamps can crush nearly 300 tons of copper rock per day and each has a large number of jigs, Wilfley tables, and revolving tables for concentrating the crushed rock. They appear like monster factories filled with busy machines, and treat between 5000 and 6000 tons of copper rock per day.

There are two immense pumps lifting a quantity of water, sufficient for one of our large Eastern cities, for the mill work.

The shops of the mine are in the main duplicated at the mills. An idea of the importance of this mine to the people may be obtained when it is stated that the Calumet and Tamarack mines together support a population of about 13,000, and the mills about 5000 more, speaking some seventeen different languages, who are being transformed into American citizens. They have their schools and churches, and furnish a market for farm and garden produce. All of this would not have existed but for the mines.

The development of gold placer-working is of interest and deserves to stand out by itself. The miner washed his sand or gravel in a pan; settling the gold to the bottom, and working off the gravel over the edge, he recovered a few particles of gold from each panful. It was back-breaking work, and he could only pan perhaps a few hundred pounds per day. The rocker or cradle with little depressions or riffles followed with two tons per day, the tom or little sluices with riffles with ten or twenty tons, the riffle-sluice with a capacity measured only by its width and the quantity of gravel that could be brought to it. The increased quantity was obtained by the giant or jet of water issuing from a nozzle five to nine inches in diameter under a head of 200 to 1000 feet, capable of moving thousands of tons of gravel to the riffle-sluice several miles long, saving many thousands of dollars of gold. At this stage an opposing interest appeared in the farmer on the low land whose river was filled with débris and his farm flooded with water. To overcome this difficulty, various schemes of retaining-dams were devised and found to a very limited degree successful. Later came the dredger, which for certain deposits holds the field to-day. It is a flat-boat floating on its own little

pond with a chain-bucket dredging-tool at the bow, a screen and riffle-tables to save the gold, and a stacker or elevator to pile up the refuse at the stern. This boat performs the curious feat of traveling across the country carrying its pond with it, cutting away the gravel in front and building it up behind. These dredgers mine, for about six cents per cubic yard, 2000 yards per day, and the gravel may run from ten cents to one dollar per cubic yard.

The dredger is self-contained, saves the gold, and does not infringe upon the rights of the farmer.

Summing up Development

And so through the various stages, the development of mining has gone on until we have the large modern mine equipped with fine machinery for excavating and tramming, those with powerful hoisting engines for lifting hundreds of tons from thousands of feet in depth, with great ore-breakers for crushing the rock, and fine concentrating machinery for enriching the ore; furnished, also, with monster pumps for removing the water from great depths and for furnishing the concentrators and fans for taking out the powder smoke and other dangerous gases, preserving the lives of hundreds of men; furnishing problems for the mechanical engineer in the handling of great masses of material with rapidity and economy; with problems in surveying the most difficult the civil engineer ever has to encounter, for example to fix exact property boundaries or to unite subterranean galleries thousands of feet below the surface, and in hydraulics for the handling of immense volumes of water to be made use of or to be got rid of, and in electricity for the transmission of power many miles from distant mountain streams to excavate, tram, hoist, pump, ventilate, and light the mines, the construction of great buildings for housing his machinery or his plants;

adapting crushing and concentration plants for the most successful concentration of the ore, and of smelting to extract the metal with the least cost and greatest efficiency and purity; the wise selection of subordinates for efficiency and loyalty; the handling of the men to get a day's work and keep them contented and happy; the financiering of the mine to get the money for opening up and developing, to keep up the dividends and the repairs and development work and sinking fund all at the same time so that the owners may feel that they get interest on their investment and get their money back after the mine is worked out.

This completed picture seems to call for a combination of mineralogist, geologist, of a mining, mechanical, civil, and electrical engineer, of a chemist and metallurgist, of a builder, a manager, and a financier, a man with literary ability and personal magnetism. Such a combination seems absurd at first glance, life isn't long enough to accomplish it, and yet, with certain provisos, it is exactly what is done.

Mining enterprises occur of all sizes from very small to very large. It transpires, then, that in the small mining venture the mining man must be able to handle all the departments specified; while on the other hand in a large mine he has many departments with department heads, mechanical, civil, and electrical engineers, builder, chemist, and others, but he has to direct all, so that a good working knowledge along the various lines is quite as important if not more so than in the case of the smaller mine.

The question may now well arise, On what lines and how should a man fit himself for this class of position? How can he best master this wide relationship of the mining engineer to the other fields?

I will attempt to answer this question in some detail. The accomplishments he needs are comprised substantially in this list:

English: He should speak, read, and write the English language well, to convey intelligently his plans and suggestions to his superiors, his wishes to his subordinates, and to read up his authorities on matters professional.

Language: He should know foreign languages for ease in conversing with foreigners and reading their works.

Literature: He should be familiar with good literature, to give him ease in meeting people.

Logic: He should understand the basis of argument, the relations of cause and effect, both as to men and things.

Mathematics: He should be able to use mathematics for clear thinking, demonstrating, and estimating.

Physics: He should be familiar with the laws of physics; mechanics, heat, light, electricity, sound, pneumatics, hydraulics, to help him act wisely in professional matters.

Chemistry: He must understand the laws of chemistry, not only as to effects of humid operations but as to effects of fire.

Drawing: He must have a good working knowledge of drawing for clear thinking, for making designs, for expounding plans to others, and for directing work.

Power: He must know the prime movers in their operation, their economy, and efficiency.

Machinery: He must understand the transmitting machinery, to bring his power to the commercial end point with the greatest economy.

Railroads: He must understand the laying out and running of railroads, including cuts, fills, tunnels, grades, tracks, switches, bridges, rolling-stock, locomotives for conveying his material.

Surveying: He must understand surveying for defining underground boundaries, for meeting underground workings, for locating, grading, roads, buildings, machines, water-pipes, ditches, wires, etc.

Mineralogy: He must know and be able to determine the minerals of economic importance, to recognize and take advantage of values when and where opportunity occurs.

Geology: He must be skilled in geology for locating deposits, in preliminary work, and for predicting the whereabouts of ore-deposits in existing mines.

Materials: He must know the materials of engineering—what, when, where, and how to use them, and also to preserve them.

Structures: He must know the principles upon which structures are built and the practice in building.

Law: He must be up in the law of contracts and of titles, to see that his company gets its rights in purchasing materials, selling materials, and in ownership of its property.

Labor: He must know the value of a day's work and see to it that his men know that he knows. He must study the labor problem so as to deal wisely in the time of need.

Business: He must understand the principles on which business is transacted so as to get fair treatment and yet keep his customers.

Finance: He must understand the principles of banking, and of establishing and holding credit.

Mining: He must understand the mining operations, safely to mine, prepare, and ship the ore or coal.

Metallurgy: He must understand the chief metallurgical operations for the common metals so as to suit the metallurgist with his ores or become a metallurgist if opportunity and inclination lead him that way.

He will equip himself along as many of these lines as he can, and establish connections for supplying those which he has not acquired.

We will now look to see what he does in return for favors received.

If we look about us, scarce an object can be seen to the production of which the miner and metallurgist have not contributed. Metal objects owe their strength to the iron or the copper alloys of the miner, their purity to the metallurgist, their beauty and decorative effect to gold, silver, brass, bronze, stone, pottery, and wood, all of them got from the mine or fashioned by metal tools from the mine. Our carriages, automobiles, locomotives move us from place to place; our wires carry our telephone and telegraph messages; our sewing-machines make and mend our garments; our saw-mills make the lumber for our houses; our harvests of wheat, corn, and potatoes, our pots and pans, knives, forks and spoons for cooking and serving food, all either themselves come from the hands of the miner or the tools for fashioning or getting them are the result of his labor; our diplomatists after doing their all with wits come as last resort to the battleship, the guns, the rifles, and the lead from mines. And, finally, the medium of all finance with which we run our mines, our factories, and with which we purchase our wares and supply our wants, whether for peace or war, is the gold from the miner's pick and shovel. We may say, then, that the work of the miner reaches the interests of all.

Coming now to the schools in which he is to prepare himself for his life's work: there appear to be three plans of education which deal with the problem of equipping men along mining engineering and metallurgical lines.

(1) The school of practice, supplemented by the correspondence school.

(2) The technological school.

(3) The university followed by the technical school.

Some pupils of all three plans reach the highest pitch of professional responsibility, as the whole question is more one of the man than of the plan. We have no reliable

statistics showing percentages of success of or proportional success. One is obliged to resort to opinion, and the opinion of no two may agree.

The especially strong point in the first plan is the intimate knowledge that is acquired of the employee class and of the minute details,—knowledge of work which is obtained in the doing of it.

The especially weak point in the first plan is that it is narrow and that progress is slow. Experiments may be more expensive to the company and in consequence a greater conservatism rules and lack of readiness to adopt new ideas even when proved.

The second plan has the advantage that in four years from the high school the student is equipped and strengthened along a sufficient number of lines so that he can do the rest if he is reasonably energetic and sensible. He may tumble down because he has not made a sufficient study of the employee class. He can perfectly well avoid this, however, by taking hold of manual work as a laborer or a miner for a sufficient time to acquire the knowledge of what men are, what they do, and how they do it. He may tumble down because he has not made a sufficient study of how to deal with men who are his superiors, or of the capitalist class. This he can avoid if he will accept every opportunity to meet men, and keep himself well read up on the progress of his profession and on affairs of public interest, together with reading of good literature.

The third plan takes six, seven, or eight years from the high school and may lead to crystallization of the man even to the point of inability to adapt himself to what is wanted of him. This is the weakest point of this school. His best prevention or cure will be to take hold of work as the laborer and miner and make an intimate study of the employee class by doing the work side by side with them. In

regard to the professional work, the third plan may or may not have an advantage over the second in consequence of maturity. The logical advantage may be offset by the time lost and by hurtful crystallization. "The college student may have learned to do nothing thoroughly well, and if he enter the scientific school after graduation may be less fit to do its work than he was four years earlier. He may have learned to depend on text-books rather than observation, and on authority rather than on evidence. The strongest point of the third plan is the knowledge the student gets of men of influence who later become capitalists. If, however, the member of the second school is energetic and sensible in working for this, it is doubtful if even this is a sufficiently strong point in favor of the third plan to give it preference over the second.

The circumstance of opportunity may come about differently in these plans of education. A fine engineer may be hidden away in some obscure position who would, if circumstances had favored him, have become renowned all over the world by the greatness of his capacity. The third plan may have some advantage in this respect, in finding out the great man and bringing him to the front. This is more an incident than a virtue of the third plan due to the men who follow it.

PRESENT PROBLEMS IN THE TRAINING OF MINING ENGINEERS

BY SAMUEL BENEDICT CHRISTY

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"THE man is always greater than his work." The training of the men who are to develop the mineral resources of the world is the most important problem connected with mining engineering. It becomes ever more important to civilization as the mineral wealth of the earth approaches exhaustion. I have therefore decided to consider a few of the more important problems arising in the training of the mining engineer, and especially those arising in America.

The Peculiar Nature of Mineral Wealth

Mining and agriculture are the two fundamental arts. Without the latter our existence would be precarious; without the former, our civilization impossible. Agriculture furnishes that regular supply of food and raiment which leads to the growth of large communities in which culti-

vated leisure first becomes possible; while mining furnishes the metallic thread from which is woven that complex fabric we call civilization.

But in these two arts the conditions for success are widely different. Most of the crops that the farmer reaps may be harvested year after year, and, the proper fertilizers being added, he may continue the annual harvest indefinitely, while, as a result of cultivation, his farm becomes yearly more valuable.

But the crop the miner reaps can be harvested but once in the history of the race. Our mineral wealth has taken unknown ages to mature in the bosom of the earth. The ripened fruit can be plucked but once. There are no fertilizers for worked-out mines. It never pays to work over a mine that has been "robbed," either through ignorance or lack of skill; and a worked-out mine is utterly worthless.

These differences between the two kinds of natural wealth have been long recognized, and have led in the Old World to a very conservative policy in the utilization of mineral wealth.

Though the fragmentary history of primitive mining-law is full of contradictions, it would seem that the development of the mineral wealth of the world was at first everywhere due to the free initiative of the miner, whose exertions were stimulated by the right to possess what his energies discovered. But everywhere in the Old World the mailed hand of the sovereign soon seized this important source of wealth and power. It was used at first exclusively for his own benefit, but as more enlightened views of the duty of the sovereign to his people spread through Europe at the end of the Middle Ages, these special rights and privileges have been used more and more for the benefit of the whole people. At the present time in some of the Continental countries individual initiative and own-

ership has asserted itself once more; still, it is generally true that in most of the countries of Continental Europe the mines are either owned or are worked under the direction of the Government. In these matters the policy of Great Britain and her colonies has been, in general, intermediate between that of the United States and of Continental Europe. Hence, in what follows I shall dwell chiefly on the differences between Continental and American customs.

Continental and American Mining-Schools

When European mining-schools were first organized they also came naturally under Government control, and there consequently resulted a close union between the mines and the mining-schools. This in turn led to many other important consequences. A regular career was opened for the graduates of the mining-schools either by their direct employment in mines operated by the Government or in the inspection and direction of the working of mines under Government control. As a consequence of this policy, well-trained men have always had the management of the mines under a sort of civil service system. And also a wise conservation of the mineral wealth of these countries has resulted; the mines are worked systematically and have often kept producing a steady output for several hundred years, while in our country they would have been worked-out and abandoned in one or two decades. While, according to our ideas, there are drawbacks to the Continental policy, it certainly lends a restraining influence to the natural uncertainties of mining life; it gives a more certain tenure of office to the mining officials; and, consequently, results in a more conservative policy in the management. It effects a more complete extraction of all the ore in the deposit, a better avoidance of wastes and a more complete utilization

of all the side products. On the whole, the system, when wisely administered, leads to excellent results.

Its effects on the early development of the mining-schools were also favorable. The close relation between the mines and the mining-schools made it easy for the one to assist the other. The graduates of the mining-schools were as sure of employment in an honorable profession as are the graduates from our Government military and naval academies at West Point and Annapolis. Historically, this connection has lent the air of distinction that clings to the profession of the mining engineer apart from his function as a mere money-getter.

On the Continent two grades of mining-schools have grown up. The *Bergschule* and the *Bergakademie.* The *Bergschule* trains working miners for the duties of mine foremen, while the *Bergakademie* trains young men of the educated class for the duties of the mining engineer.

The system here outlined possesses many advantages and is admirably adapted to the countries where it originated. But it would be impossible in America. In the first place our Government gives away its mines and does not attempt to control either them or the mining-schools. No official connection either exists or is possible between them. Moreover, though there is much to be said in its favor, the sharp distinction drawn between the *Bergschule* and the *Bergakademie* in Europe is at variance with American ideals of democracy.

It has become an axiom with us that not only genius, but also talent, ability, and capacity of any kind, are too precious to the entire community to allow them to go to waste. We err, indeed, by going to the other extreme. But there is no doubt that the wonderful industrial progress of America is largely due to that equality of opportunity that is here practically open to every young man of ability.

The American Temperament

It has often been claimed that the American temperament is due to our peculiar climatic conditions. As a matter of fact nearly all the climates of the globe characterizes our country. And in order to disprove this theory one has only to cross the narrow line that bounds our country either to the north or to the south to find a relief from the strenuosity of the American temperament. The American temperament is due, not to climatic conditions, but to a mental attitude toward life. When a man feels that his future depends not so much upon his own efforts, but mainly upon the position to which he was born, he is, if not contented with his lot, at least more likely to be reconciled to it; for he feels it idle to waste himself in useless effort. But if you can convince such a man that there is no limit to his ambition but that of his own powers, you have fired him with the most powerful stimulant that can influence human nature. It is this stimulant, working day and night for over a century upon men descended from every race in Europe, that has produced the American temperament.

It is a temperament that was not unknown in Greece in its great democratic days. Republican Rome felt it too. But in monarchies its influence is mostly confined to the army and the navy. For in war times the best man must be had regardless of his birth. Napoleon overran Europe by declaring to his men: "Every soldier carries the Marshal's baton in his knapsack."

The Rôle of "the Practical Miner" in America

Nowhere in America has this influence been more keenly felt than in the mining industry, particularly in the Western States. The policy of our Government in throwing open to the hardy prospector its ownership in the mineral wealth

of these states has stimulated men without previous technical education and training to accomplish what in older countries would be regarded as physical impossibilities.

It is true that the path has been marked with waste of money, labor, and life. Blunders, failures there have been, and still are, innumerable. But the accomplishment is all the more remarkable when we recognize these facts, for it testifies to the almost superhuman energy with which these obstacles have been overcome.

We are greatly indebted to the Old World for its contributions to the mining and metallurgic art, but we are beginning to repay the loan with generous interest. And, to tell the truth, it is largely due to the plain average American, without college education or training, that many of these advances have been made. Every one who has mixed much with American miners has met and honored many such uncrowned kings. *And unless the graduate of American mining schools is ready and willing to meet with this kind of competition without fear or favor, he will surely and deservedly fail.*

This was the first great problem that confronted the American mining schools and it has proved their greatest advantage. There is no royal road for their graduates. They cannot depend on the Government for places in the mines, because the Government neither owns, works, nor attempts to control the mines. Neither can they look to their diplomas as a guarantee of employment.

The American attitude on this question has hitherto been very different from the European. Credentials, degrees, diplomas, and recommendations that in Europe carry great weight, in America often receive but scant attention. The American often amuses himself with titles, but deep down in his nature is an instinctive distrust of any one who takes them seriously. Among the men who have done most to

develop the mineral wealth of our country this feeling is particularly strong. What a man is, is more important to them than who he is. What a man knows interests them but little; it concerns them much more, what use he can make of this knowledge.

Herbert Spencer, a radical in so many of his opinions, was quite in sympathy with this point of view. I quote from his *Autobiography*, vol. I, p. 199, beginning with a passage from a letter to Herbert Spencer from his father:

" 'I am glad you find your inventive powers are beginning to develop themselves. Indulge a grateful feeling for it. Recollect, also, the never-ceasing pains taken with you on that point in early life.' "

Herbert Spencer then adds:

"The last sentence is quoted not only in justice to my father, but also as conveying a lesson to educators. Though the results which drew forth his remark were in the main due to that activity of the constructive imagination which I inherited from him, yet his discipline during my boyhood and youth doubtless served to increase it. Culture of the humdrum sort, given by those who ordinarily pass for teachers, would have left the faculty undeveloped."

Footnote by Mr. Spencer: "Let me name a significant fact, published while the proof of this paper is under correction. In *The Speaker* for April 9, 1892, Mr. Poulteney Bigelow gives an account of an interview with Mr. Edison, the celebrated American inventor. Here are some quotations from it: 'To my question as to where he found the best young men to train as his assistants, he answered emphatically: 'The college-bred ones are not worth a——! I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work.' Mr. Edison did not conceal his contempt for the college training of the present day in so far as it failed to make boys

practical and fit to earn their living. With this opinion may be joined two startling facts: the one that Mr. Edison, probably the most remarkable inventor who ever lived, is himself a self-trained man; and the other that Sir Benjamin Baker, the designer and constructor of the Forth Bridge, the grandest and most original bridge in the world, received no regular engineering education."

Mr. Spencer might have added himself to this list of remarkable self-made men, for his schooling, though excellent as far as it went, was very meagre, and he made himself what he came to be.

In the words: *"I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work,"* Mr. Edison has put his finger with singular acuteness on the principal failing of improperly trained college students. The reason why they are not willing "to begin at the beginning and give their whole heart to the work" is because their education has often been so exclusively theoretical that they are filled with the conceit of learning, and they have an inordinate idea of their untried abilities. Hence their unwillingness "to begin at the beginning." They feel that they ought to begin at the end and be put in charge of everything. If, in their training, theory and practice had gone hand in hand, this conceit, which is natural to all young men, would have been soon dissipated by the hard realities of practice, and the young men would have been more willing "to begin at the beginning," and more ready and able "to give their whole heart to the work."

At the same time I cannot help thinking that Mr. Eaison must have been unfortunate in his choice of "college-bred assistants," or in the colleges that trained them; for in opposition to his experience may be quoted the practice of a large number of his important rivals in the electrical business and of an increasing number of iron and steel railway

bridge construction, and mining and smelting companies, to draw upon the graduates of engineering schools for their assistants; and where they wisely insist on the men beginning at the bottom and working their way up according to merit, the results have been, on the whole, more and more satisfactory as the engineering schools have adjusted themselves more closely to their environment. I have given these strong statements of the failings of college-bred men, not to indorse them, but because they contain an important truth that must be recognized and met.

This condition of public opinion has from tne very first forced the American mining schools to stand on their own merits. Whatever success they have achieved has been due to this hard necessity.[1] The atmosphere surrounding European mining schools is so different from that in America that graduates from such schools have always found in America much to be unlearned. The American mining schools have already adapted themselves so well to their environment that this year, for the first time in nearly a century, there were no American mining students in the great Saxon Mining School at Freiberg. And already

[1] I append in this connection the following concise and caustic note from the *Engineering and Mining Journal*, p. 403, June 12, 1880, which shows the condition of affairs in America only 25 years ago. The hope expressed in the last paragraph has since been largely realized to the benefit of all concerned.

"A correspondent writes us, asking 'If it is absolutely necessary to be a graduate of a school of mines before being able to engage in the business of a mining engineer.' Certainly not; in fact, before engaging in the business of mining engineering it does not appear to be absolutely necessary that a man should know anything at all, as our correspondent can very well satisfy himself by visiting nine out of ten of the mines nearest to him, wherever he may be. Had our correspondent asked, whether it would be desirable that a man should be a graduate of a school of mines before engaging in mining engineering, we should have answered in the affirmative, for the simple reason that the course of study in a school of mines is calculated to give the elementary education necessary for a mining engineer, and, other things being equal, should give its recipient an advantage over those who have learned the business only in practice. The course of study in a school of mines is not, however, sufficient to qualify a mining engineer to take charge of important works; but it forms an excellent foundation upon which to build a practical knowledge of the business.

"Many of our mines are now under the direction of competent engineers and the results of this policy are justifying the hope that, before very long, all companies of good standing will place their mines in charge of men specially trained for the discharge of the responsible and important duties of a mining engineer."

some of the American mining schools have exceeded in wealth, in equipment, and in attendance, this most famous of all mining schools.

Is Theoretical Training Worth While?

But, it may be urged, if practical men without theoretical training have accomplished so much, what is the use of theoretical training? Why not confine the education of the mining engineer to the purely practical part, omitting all the theory? The answer is not far to reach. The purely practical man has indeed accomplished wonders, but at the cost of enormous waste of money, labor, and human lives. For every success that he has made there are a thousand failures which only the thoughtful notice. There is no profession where practical experience is more essential than in mining, but the necessity of a sound scientific training is even more indispensable. A hard-headed Arizona miner once put the matter very tersely when the superiority of the "practical man" was being strongly urged, by saying: "I have had thirty years' practical experience in mining, and I would give twenty-five of those years to have had a good technical education to begin with." He was clearly right, for a man well trained in fundamentals has a broader grasp and can more intelligently and rapidly utilize his experience than a man without this training.

Either theory or practice alone is helpless; united they are invincible. And the brilliant success of the American mining engineer in so many fields has been because these two important elements have been so thoroughly blended in his training.

Specialization, How Much and When?

This problem arises from the great breadth of training which has been necessary to the American mining engineer.

Like the soldier or sailor, he must go to the ends of the earth. His work often lies beyond the borders of civilization, where, like Prospero upon his lonely isle, he must conjure up his resources from the vasty deep; and he must act in turn as geologist and as civil, mechanical, hydraulic, electrical, mining, or metallurgical engineer. The problem is: What degree of specialization shall be undertaken in an undergraduate mining course? Shall we endeavor to turn out at graduation specialists, each completely equipped for work in some narrow line, or shall we rather attempt to establish a broad basal training in the physical sciences on which the future engineer may safely build, as circumstances may require?

The former system is the European practice, such parallel courses as mining engineering (further subdivided into coal- and metal-mining), metallurgical engineering (also subdivided into two branches), mine-surveying, mine-geology, and the like, being commonly recognized departments within which the student specializes in an undergraduate course.

In an old community, where the mines are under Government control, and customs have crystallized, such a specialization is wise. Each student can estimate with certainty the need for the specialty he chooses, and be sure of employment in his own line.

But under American conditions (with a few notable exceptions, where conditions have become relatively stable), it is unsafe to specialize too soon and on too narrow a basis. Here the mere specialist, outside of his specialty, is as helpless as a hermit crab outside of his shell, and unless he possesses the ability to adapt himself speedily to a rapidly changing environment, is sure to go under. The present age in America is one of rapid change in all industrial and engineering methods, such as has never been seen in the

world before. Old established processes are being continually swept aside and replaced by new ones. These changes occur with kaleidoscopic speed and unexpectedness; and the man who has painfully armed himself with precedent and ancient lore finds himself hopelessly beaten before he can even make a start in the race. The American has always been characterized by his fertility of resource and power of adaptation. This has been his strength; his weakness has been his impatience to plunge into practice without a sufficiently broad and deep scientific training.

Fundamentals First

I believe that we can trust to the American instinct of adaptability without much further attention. But that which is most necessary is to insist more and more on a solid foundation of scientific training to begin with. If we can secure for the American mining student a foundation training broad, deep, and thorough in mathematics, physics, and chemistry, he needs little else to make him invincible. The mining engineer must have a broader basal training than either the civil or the mechanical engineer, even though he specialize less. Mathematics, physics, and chemistry are necessary for all engineers; but for the civil engineer mathematics is fundamental, for the mechanical engineer physics is equally so, while for the mining engineer we must not only add physics, but also chemistry, with her closelv related allies, mineralogy and geology.

The training of the mining engineer cannot be too thorough in all these subjects. Each is an essential support to any superstructure that he may desire to build in the future.

Mathematics should include the differential and integral calculus, the theory of probabilities, and the methods and criteria of approximations. A firm grasp of space-relations as developed in descriptive geometry is peculiarly important

in following geological structure and vein-formations in the deeps of the earth. The mathematical work should be made familiar by numerous applications to concrete cases in which numerical results should be insisted upon. In this connection it is particularly important that the engineer should be made to realize that the most important part of his numerical result is the position of the decimal point, and only after that, the value of the first significant figure. Mathematical instructors too often neglect this, to the engineer, most vital matter. The sense of it should be made instinctive. It is much more important that mathematical instruction should be thorough as far as it goes than that it should feebly cover a large territory. The subject should be so thoroughly mastered that it comes to fit the hand like a well-worn tool.

No man is fit to teach mathematics to engineers who has not had some experience in its applications either to engineering, to physics, or to astronomy. For only such a man knows just what to emphasize and what to omit, how to sympathize with and how to inspire his students.

Men of prime ability in the mathematical faculty are absolutely the first essential in any engineering school. It is wonderful how difficulties melt away like wax in the fire with a really able mathematical teacher. By such a teacher mathematics can be made as interesting as a romance to the average man; while it is often regarded as hopelessly difficult merely on account of the poor hands in which it is placed. To make new discoveries in the field of mathematics requires genius of a high order; but to master all the mathematics necessary for the intelligent practice of engineering requires no faculties beyond those of a logical mind, a certain power of imagination, and a reasonable degree of application. I have always found that the students who do well in mathematics do well in everything else that requires close thinking.

Instruction in physics and in mathematics should go on side by side; and the two courses should be so arranged that the mathematical principles may be at once applied to physical problems of a useful nature. The importance of actual numerical results should be always insisted upon. The student should be trained in the arts of observation and in inductive as well as deductive reasoning. He should acquire practice in the theory of approximations and should form the habit of judging or "weighing" his own results and of checking them by independent methods.

While the whole field of physics is important, the fundamental conceptions of analytic mechanics (acceleration work, kinetic and potential energy) and their applications in hydraulics, thermodynamics, electricity, and the like are vital, and cannot be too much emphasized.

Instruction in chemistry should be given parallel with mathematics and physics. It offers a fine training in inductive reasoning. Besides the usual courses in general and analytic chemistry, the modern methods of physical chemistry, as developed by such masters as Arrhenius, Ostwald, Nernst, and van't Hoff should be brought to the attention of the student, as soon as, by his collateral training, he is made able to understand them. It is not too much to say that the hope of the future, not only in biology, medicine, and hygiene, but also in physical geology, the science of ore-deposits, and the art of metallurgy, lies in this direction.

Such subjects as drawing, surveying, and mapping may also be carried on simultaneously with mathematics and physics, each supplementing the other. Similarly, assaying and mineralogy give a new interest to chemical principles, to which they serve as useful applications. Geology itself, important as is this noble subject, not only through its intrinsic interest, but also in its practical bearings, is

really only an application of the principles of physics and chemistry to the study of the evolution of the earth. And it can be mastered only by him who has this training to build upon.

The same is true of every branch of engineering. Each is only the outgrowth of the application of the principles of the fundamental physical sciences to the needs of man. He who has this training has the master-key to the door of every industry.

The necessity for thoroughness in this fundamental work cannot be too much emphasized in American mining schools. The impetuous preference of young Americans for what they deem "practical" is a serious hindrance to real achievement; and the only way to remove it is to convince them at the very start of the power and value of science. This can best be done by leading them, from the beginning, to apply science to some useful purpose. In short, they must be taught by experience the truth of Ostwald's saying: "The science of to-day is the practice of to-morrow."

There is much to be said in favor of the study of science for its own sake. We have all sympathized with the sentiment of the mathematical professor who "thanked God that he had at last discovered something that never could be put to any practical use." Still, it is a healthful instinct that leads most men to estimate the value of ideas by the use that can be made of them, and whether we approve it or not, the world will continue to do that, and we may as well adapt our plans to the fact.

To the man thus fundamentally trained nothing is impossible. He may still need to be made familiar with the general scope of each of the main branches of engineering, their relations to each other, the nature of the problems that each is called upon to solve, and the leading methods which,

in each branch, have stood the test of time; and he should be made sufficiently familiar with the literature of the subject to know where to go for needed particulars; but any attempt to cram his memory with the details of methods that may become obsolete, before he is called upon to use them, is a distinct and fatal mistake.

The Organizing Faculty

The successful engineer is a creative artist in the use of materials and energy. In this class, he stands first who with the smallest means produces the greatest results. Success will come most surely to him who clearly sees the nature of each concrete problem, and, from the widest outlook, chooses just the right methods, materials, and forces of men and nature, to bring his undertaking to a successful issue.

Among engineers the creative or organizing faculty is a natural gift as rare as any other kind of genius. But fortunately it is a faculty most Americans have, at least in embryo, and it can be cultivated. All the work of a mining school, whether in the basal sciences or in the technical branches, may be utilized to develop it. Instead of possessors of encyclopedic erudition, there is needed a type of man that may mechanically remember less but can do more. Such a man learns to analyze each problem that comes before him; when necessary, he runs down the literature bearing upon it; selects the good; rejects the bad; supplies by ready invention the missing link; decides what must be done,—and *does it,* cleanly, rapidly, and with certainty, while the "encyclopedia maniac" is still digesting his erudition.

This kind of training, repeated again and again with every subject studied in the college course (at first in small and simple problems, later in larger and more complicated

ones), does more to create the engineering faculty than anything else that can be devised. It is only by actually doing things that we learn how to do them. Action must follow reflection, and reflection must precede action for successful and useful life. Unless action follows reflection, life is "sicklied o'er with the pale cast of thought." Unless reflection precedes action we have all the ills that follow impetuosity, of which anarchy is the final and the bitter fruit. From this point of view the training of engineers has a moral effect on the whole body politic, since it tends to create a solid, well-balanced element in the community. Nothing develops a good man sooner than responsibility, which forces not only reflection, but action also. And the sense of power that comes with the successful exercise of the creative faculties in the engineering arts is one of the purest and keenest pleasures of which our nature is capable.

The greatest service those in charge of the higher technical branches of the mining school can render their students is to show them how to apply their scientific knowledge to such practical problems as come before them. He who can do this for his students, and can give them a taste of that sense of power that comes from a mastery of the forces of nature, can trust them to go the rest of the road without a finger-post to point the way.

Personal Contact with Working-Condition

I have said that the mining engineer should learn to see clearly the problems that he must solve; that he must be familiar with the materials and the forces, not only of nature, but of human nature, with which he must work. How shall he gain this knowledge? There is only one way: To become familiar with them by actual contact.

Should this experience come before, during, or after the college course? It is most useful when it comes in all three

ways. But coming only after the college course, it is altogether too late. Before that course, it can be usually gained only at the sacrifice of that general training, particularly in the languages and the humanities, that is so important to us all; and, moreover, before college-age the student is usually physically too immature to undertake such work. For these reasons it is usually best to let this experience begin with entrance into the mining-school. In each college year, as commonly arranged, from three to four months are given to vacations, which, occurring at regular periods in summer and winter, are admirably adapted to a progressive course of practical work in surveying, mining, and metallurgy, in which the student can familiarize himself with practical conditions in different localities. For the reasons already given, this work should begin with the school course, and be carried on progressively, at regular intervals, with the theoretical work. It is thus practicable for the student to gain nearly a year of experience in a considerable range of methods. He is thus in a position to determine his own fitness for the work; to learn the branches for which he is best adapted, and for which there is most demand; and to make acquaintances that will be useful to him afterwards. If he shows aptitude for the work, he is reasonably certain of finding the place for which he is suited; and if he does not, he can adjust himself to some other calling without further waste of time.

The importance of this training for the mining engineer is greater than in any other branch of engineering; for the conditions that he must meet are entirely different from those of any other calling. But it has been much more difficult to secure it under American than under European conditions. Besides the lack of official connection between the mines and the mining schools, there has been a strong prejudice against college students on the part of practical

men. This is partly due to experience with men trained exclusively in the old classical course, and almost helpless in practical affairs, because absolutely without knowledge or sympathy with nature. But it is also partly due to the self-assertion, flippancy, and conceit of which young men just out of college are often guilty.

The "Mining Laboratory"

Several solutions have been proposed to meet this difficulty. The first and most original is the so-called mining laboratory, perfected through the pioneer work of Prof. R. H. Richards of the Massachusetts Institute of Technology. This has since become a prominent characteristic of American mining schools generally, and is now being adopted in Europe. According to this plan, the leading operations of crushing, concentrating, and working ores are executed by the students on a small working-scale in the laboratories of the school itself. In this way the schools have become partly independent of the mines, so far as the study of metallurgy and ore-dressing is concerned. In purely mining practice the problem is more difficult. I have for ten years, with some success, made an attempt in this direction, so far as rock-drilling and blasting are concerned. For this purpose, a mining laboratory has been provided, in which the operations of sharpening, hardening, and tempering drills, and the single- and double-hand drilling of blast-holes, as well as machine-drilling, are illustrated on a working-scale. Later, with the aid of an experienced miner, the operations of blasting are conducted by the students in a neighboring quarry. In the new mining building, provided for the University of California by the generosity of Mrs. Hearst, it is proposed to extend this work, as far as practicable, to other branches. These devices have all proved very useful in familiarizing students with important

current methods, under conditions where they may be controlled and studied in detail, even better than in the hurly-burly of practice. The mining laboratory is one of the most important of the efforts of American schools to adjust themselves to their environment.

The Summer School of Practical Mining

But helpful as this method has proved to be, it still fails to bring the student face to face with the actual conditions of mining practice. The next important step was taken by Prof. Henry S. Munroe, of the Columbia School of Mines. For many years he has devoted much labor, with notable foresight, judgment, tact, and discrimination, to the system now known as the Summer School of Practical Mining. To him, more than to any other one man, we owe this very useful adjunct, which has been adopted, with various modifications, by most American mining schools. It is an outgrowth of the geological excursion, so long practiced in German mining schools. But here it has been made to comprise the study, by a body of students, under the direction of their professors, of the leading operations of mining, dressing, and working ores. One or more mining districts and several mines are visited, during a trip of a month or more. Surveys are made; sketches and notes are taken; and the student begins to acquire a first-hand knowledge of many conditions which he must afterwards meet.

An interesting modification of this method has just been attempted jointly, at the suggestion of Prof. John Hays Hammond, of the Sheffield School, and under the direction of Prof. H. S. Munroe, of Columbia, by the mining schools of Columbia, Colorado, Harvard, the Massachusetts Institute of Technology, and Yale. It consists in hiring a mine for the summer, and putting the students at work under proper direction at the various operations of

practical mining. In this way the mine for the time being is turned into a sort of school for the young men. This change certainly has many advantages. It comes as near the European conditions as is possible in America. It enables the operations of the mine to be subordinated for the time being to the needs of instruction. This, for beginners, is certainly a great advantage. The method is, however, an expensive one; and several years of experience are necessary before it can be finally judged.

There is another modification of the summer school idea, perhaps even more difficult of general application, with which I have had the most experience, and from which I hope much in the future. I began by visiting with my students various mining districts each year; but I found in this plan not only many advantages, but also many serious difficulties. One of the most fundamental of the latter was, that there is an important element which a man does not get by merely looking on. He often thinks he understands a thing that he sees another do; but such superficial knowledge is not to be trusted. It may suffice for amateurs and *dilettanti;* but real professional knowledge and power are not so obtained. It leads to that false sense of knowledge that makes practical men so disgusted with the man just out of college. It is the thorough, ingrained mastery which long familiarity with his work has given the practical man that makes him superior in any emergency to the mere "looker-on in Venice." Moreover, traveling with a large body of students tends to emphasize the difference between the students and the miners, and to make each party self-conscious, and, to a certain extent, antagonistic. When many students travel together, they carry with them the college atmosphere, which is the very thing they need most to get away from, in their vacations. It is only when such a body of students is so diluted by dispersal among a

large number of mines and miners who are *working* and *not playing* at mining, that they can be made to realize that they are not "the whole thing;" then, and then only, are they in a position to derive any real benefit from their experience.

These views were gradually forced upon me, as they doubtless have been forced on others, by a study of results. Moreover, as the number of students in the classes increased, I found it more and more difficult to secure accommodations for them in any but a few large mining centres. This greatly limited the practicable scope and variety of the work.

But the cause that finally decided me to make a change was the lack of means, among some of the best students, to pay the expenses of such trips, in addition to those of the college course. Some of these men asked to be permitted to work for wages, instead of attending the summer school. This was done in certain cases; and I found at once such an improvement in the subsequent work of these students that I decided to alter my general plan accordingly.

The method, as thus far worked out, is to require that each student shall spend at least a month underground in the study of practical mining. As a matter of fact, most of the students thus spend from six to eight months during their college course, and many of them even more. Each must prepare a well-written account of his experiences, together with an essay, on a subject chosen by himself from among those that interested him most. These papers are read before the whole class and are discussed and criticised by all. Many of them have been extremely interesting and instructive.

The students are not required to work for wages, and are even discouraged from doing so, unless they are physically mature, and have some familiarity with the work. But

all are strongly urged to attempt this before they graduate. Most of them need very little encouragement; in fact, they take to it as naturally as ducks to water. There is a time in the development of a young man when hard work seems to be a physical necessity—an assertion of his manhood. It has even come to pass among us that the young man who, from physical or other disability, does not do so, loses caste among his fellows.

There is of course a certain disadvantage in working for wages. A man has to do the same thing over and over again and is usually too tired to think much while doing it. But this objection is easily removed; for when, by a month or more of hard work, a man has established himself and paid his way, it is very easy for him to take further time at his own expense to get a general view of the work as a whole. Some men are of course physically unable to perform manual labor for wages. But unless they are unusually well adapted for the profession in other ways, such bodily weakness is generally an indication that they had better adopt a less strenuous occupation. I have never found that the men have been lacking in mental grasp from having to work; though naturally one cannot do hard labor and take voluminous notes on the same day.

On the other hand, there are certain great advantages in working for wages. It gives a man a just self-confidence, as nothing else can. He feels that no matter where he may be he can hold his own among men as a man. He learns the point of view of the working miner, and how to win his confidence and respect. He gains an inside knowledge of the errors and successes of mine administration. He comes to know the meaning of "a day's work," the tricks and subterfuges by which inefficient workmen seek to evade doing their duty, and the way to treat such cases without unnecessary friction. Such an experience is sure to prove

invaluable, when, as he grows older, he is himself intrusted with the management of men. He will be more likely to know how to avoid unnecessary conflicts with his men from having himself "borne the heat and the burden of the day."

As a rule, men without previous experience are put first at loading and tramming cars, and later, at single- or double-hand drilling, or as helpers on a machine-drill; while in small mines they often have experience at timbering or at the pumps. Many of the men are really able to earn full wages as miners, before they get through. Often, when hard pressed for resources, they work a year, or even two years, underground, thus earning enough to pay their way through college. This seems rarely expedient, except in cases of necessity. But there are some cases in which an excess of animal spirits finds in such a rustication a natural outlet, and the man is really made over again by such an experience.

The men are advised not to go in groups, but usually in pairs, since, in case of illness or accident, a faithful "pardner" is a great source of comfort. They are also advised to scatter in a thin skirmish-line over the whole mining regions west of the Rockies. Some go as far south as Mexico, others find their way to Cape Nome and the Klondike. Thus, like bees from the hive, they scatter over a wide area; each brings back honey of a slightly different flavor; and all benefit by this richer store.

Many difficulties were encountered, particularly at the beginning, in carrying out this plan. Many still remain to be overcome before it can be perfected. It depends for success, not only on the good will of the miner and the mine-owner, but also upon the discretion and tact of the student. I have always found the miner, and nearly always the mine-owner, willing to help any young man of good physique and good nature who was not overcome with

a sense of his own great knowledge and importance. But when a very young man sets out, unasked, to show another man, old enough to be his father, how to run a mine, there is naturally trouble,—as there ought to be. For the first lesson a young man has to learn is the necessity of adapting himself to his surroundings, and of fitting himself into his place in the greater mechanism; and until he learns this, his lot is likely to prove rougher in the mining world than anywhere else.

There is much to justify the prejudice against a man who goes to college simply to escape doing his share of the world's work. Consequently, I have advised my students never to ask for work *because* they were college students, but simply because they were able and willing to earn what they were paid. In short, I have advised them to secure in their vacations the advantages of the "Wanderjahren" of the German apprentice. By scattering over a wide territory they are absorbed very naturally, and, as a rule, without much difficulty. Some of them have learned hard lessons not down in books, but it has done them good.

The men are all advised as to the principal precautions to be taken to preserve their health, the dangers they will have to meet, and how to meet them. They are plainly told that unless they are ready to take the hard chances of the miner's life they had better choose some other occupation.

Among more than a thousand students who have participated in this work during the last fifteen years there have been but two serious accidents. Both of these were fatal. The victims were young men who had been working for nearly a year in the endeavor to earn enough money to pay their way through college. One was caught in a cave. The other, in firing a blast, had his candle blown out by the spitting fuse, and, in the darkness, was unable

to reach a place of safety. But these very accidents have served to convince the mining public that the California boys were enough in earnest to face the dangers of the miner's life.

This attempt at a solution of the problem is not presented as a general one; it is probably better adapted to Western than to Eastern mining conditions. It can only be applied when there exist a large number of mining camps within easy reach of the mining school. Its best feature is, that it falls in with the American idea of free initiative. Moreover, it serves admirably to select the fit and reject the unfit without loss of time. It also automatically adjusts those questions of supply and demand that are so hard to settle.

In spite of its many imperfections, the system is beginning to bear fruit. The opposition to college men is growing gradually less. It is found that most of them are in earnest, and are willing and able to work, and that some of them have ability. Before the term of work is over a man is frequently told: "When you have finished college, I may have something for you to do." Many a man has dropped in this way into just the place for which he was adapted.

In short, if the college man can overcome the prejudice against him that often exists all too justly among men of affairs, by showing that he really is a man, modest, willing, and capable, his education will have its chance to count in the end, as it does more easily at the beginning, under Old-World conditions. The only chance to make his start that the American mining student has, is to meet the practical man on his own ground. He can always do this if he has the courage to break the ice. It is better and easier for him to do this before he graduates than afterwards.

Physical and Moral Soundness and the Coöperative Spirit

Experience on these lines has emphasized the importance to the mining student of a sound and, if possible, a robust physique. By this I do not mean heavy muscles merely, but essential soundness of the vital organs, particularly those of digestion, circulation, and breathing, and also the senses of sight and hearing. Important as these possessions are to all, to the mining engineer they are indispensable. An early physical examination by an experienced physician should reject all defective candidates as rigorously as is done in the army and navy. This should be followed by a thorough physical training, whose aim should be the production of a sound and healthy man. Some instruction in the fundamentals of hygiene, the precautions necessary in the use of food and water, the precautions to be taken in malarial regions and some knowledge of the "first aid to the injured," are very useful to men who must often serve as leaders of a forlorn hope in a strange land.

Even more important than physical soundness is moral soundness. It is absolutely necessary that mining engineers not only see the truth, but speak it. Scientific training, when thorough, always develops one important moral trait. It helps to elevate the love of truth into a religion. This is its greatest moral service to society.

In this connection we are all under indebtedness to the late Mr. A. M. Wellington for his able articles on "The Ideal Engineering School."[1]

Speaking of the young engineer, he says: "He must be truthful and worthy of trust, must mean what he says and say what he means. If he cannot do this he must be silent." And again: "All men whose advancement depends on those above them must not only *be,* but also *seem,* faithful to those above them."

[1] *Engineering News,* — 1893.

He calls attention to the fact that the lawyer, the physician, and, to some extent also, the clergyman, depends for his success almost entirely upon his individual knowledge and intellectual abilities. Such a man may or may not be personally agreeable to those for whom he works; it is his knowledge and his technical skill that we wish to utilize in an emergency. These are his own possessions, and he can utilize them unaided and without the coöperation of others.

But with the engineer this is not the case. His work cannot be done except through the friendly aid, not only of many engineering co-workers, but also through the help of capital and labor, the two most difficult elements in our civilization. From the inception of the original idea to its final completion, men and money, brains and brawn, nature and human nature, must work together without friction for a common purpose.

The young engineer must win the confidence of his superiors by a faithfulness and loyalty, free from subservience; he must secure the good will and liking of his equals by frankness and openness of nature; he must command the respect of his subordinates by his evident mastery of his business, his sense of justice, his freedom from petty meanness, and his fearlessness in the discharge of duty. The man who cannot meet the requirements of any one of these three relations, no matter what his knowledge and technical skill, is sure to fail. And because they possess these qualities in a high degree, many men of very ordinary abilities often succeed as engineers, when men of superior genius lamentably fail.

When men must work together day and night, side by side, in intimate personal contact, where relations of subordination and command necessarily must exist, there must be no friction. Even a slight uncouthness of nature, or rudeness of manner, objectionable personal habits, or lack of tact, becomes simply unbearable at such close quarters.

All this is most emphatically true of the mining engineer. No men except soldiers, sailors, explorers, and astronomers are subject to such a strain on their endurance.

As was also pointed out by Mr. Wellington, the necessity for the cultivation of the social graces and amenities of life, for habits of personal neatness, for self-control and uniform good nature under conditions of hardship and privation, have always been recognized as essential qualities in the army and the navy. That it is possible to cultivate these qualities, even in the most heterogeneous material, is evidenced by the success of our military and naval academies in producing them in the average American youth. The raw material they have to work on is not different from that which goes to our engineering schools. But the results they attain in this respect are so decidedly better that there is no comparison. In most engineering schools these important qualities are simply ignored, and no attempt is made to cultivate them.

Where, as in many of the so-called "Land Grant Colleges," a certain amount of military instruction and discipline is required, the means exist by which these qualities may be cultivated to some extent. In the University of California such is the case, and I have always found that the mining students who, by attention to such matters, succeed as officers, invariably take high rank in their profession in executive positions. It is one of the few chances men have in college of learning the arts of controlling themselves and others. There is no agent so effective in forcing men to realize the means and advantages of coöperation as rigid military discipline; for the wars and struggles of our race since primeval times have polished and perfected this method till it has reached a high state of efficiency. But it is difficult for engineering schools to give the time and attention to it that is possible in a purely military school.

Another important means of reaching this end is to be found in all athletic sports in which, as in baseball, boating, and especially in football team-work, plays an important part.

Organizing students into parties for surveying and other field and laboratory investigations, where each in turn acts as aid and as chief, is another effective means. In short, any agency that develops the instinct of coöperation, of team-work, of the faculties of self-control, courtesy, fidelity, and faithfulness, will prove effective. It will be more difficult to secure these qualities in America than it is abroad, because of the strong instincts of individualism and self-assertion that are such marked characteristics of American youth. Nevertheless, the uniform success of Annapolis and West Point in these matters testifies to its possibility. There is great room for improvement along these lines in all American engineering schools.

Sundry Minor Essentials

There are also certain minor matters, too often neglected by both students and professors, which are peculiarly important to the young engineer in his first work after graduation, and all of which can easily be mastered in college; such as, neatness in drawing, mapping, and lettering, certainty and rapidity in numerical work; in the measurement of angles and distances in surveying; and in sampling, assaying, and the common methods of analysis. At first, accuracy is more important than speed. But the latter is, in practice, only less important, and should be insisted on from the beginning. A sound judgment on the degree of precision needed for the particular purpose in question is also indispensable. The student should be sure, on the one hand, that his errors do not exceed this limit, and, on the other hand, that he does not waste time in needless refine-

ment when approximations suffice. He should form the habit of always checking his measurements and calculations by at least two independent methods. The only way to insure this standard of accuracy and dispatch is to hold him to the hard standard that he will have to meet in practice, and to make him realize that for carelessness or blunders no explanations can be accepted. Rigid discipline on these lines should begin in the mathematical, physical, and chemical departments, and should run right through the higher technical work with increasing severity. Tolerance of blunders is cruelty in the end.

General Training

The mining engineer needs a certain fundamental training in economics, by reason of his position as an intermediary between capital and labor; his necessary dealings with merchants and contractors; and his handling of questions as to the valuation of mining properties and the financing of mines. Besides the broad questions of money, interest, wages, and other leading topics of economics, it is also important that he should be familiar with the laws of specifications and contracts, of ordinary business usage, the science of accounting, and the law of mines and water.

The broader the general culture with which a student comes to the mining school the better. The minimum entrance requirement should include some familiarity with general history, with the best of English literature, and the command of a simple, clear, and forcible English style. A reading power of the leading modern languages is only less necessary than a mastery of one's mother tongue.

As the training of the mining engineer must of necessity be chiefly scientific and technical, its natural tendency is to put him somewhat out of sympathy with the gentler side of human culture. It is important to counteract this tend-

ency by keeping him in touch with the finer arts, by which life is mellowed, enriched, and ennobled.

Where, as is frequently the case in America, the mining school is an integral part of a great university whose scope includes all the activities of our nature, this end is easily and naturally reached by the association of mining students with other students who are devoting their lives to the arts, to philosophy, and letters. The student is thus forced to become familiar with a wider outlook. Some touch with one of the finer arts, such as music, painting, or sculpture, that will bring out the innate love of ideal beauty that exists in every man, is necessary to a well-balanced nature. Perhaps the most important of these influences is the cultivation of a taste for general literature, whose possession is a refreshment to the soul. The mining engineer who possesses it takes with him to the ends of the earth an inspiration that must make him an agency of moral and spiritual uplift wherever he may be.

Location of Mining Schools

Which is the better location for a mining school,—a mining centre or a commercial one? Successful mining schools have been established in the older countries in both situations; Freiberg, Clausthal, Przibram, and Leoben are examples of the former; and Paris, Berlin and London of the latter. Historically, the first to be established were in the mining centres, which have the advantage of surrounding the student with a professional atmosphere, in which all the activities and ambitions of life gather about this one industry. When means of communication were poor, such a location was almost indispensable.

But such a location tends to make the training of the mining engineer provincial when it should be universal. Moreover, even in Europe, an end comes at last to a min-

ing district, and the mining school becomes stranded in a dying community. Some of the most famous of the European schools are already approaching this condition, which yearly becomes more desperate.

It is for this reason that the modern tendency is in the opposite direction. The most permanent of human institutions are the great commercial centres, made so by natural physiographic features, that facilitate intercourse, which is the life of trade. The capital that develops mines comes from these centres, and the profits from the mines return to them. The enterprise that undertakes great ventures has its source there, and thence, confining itself to no national boundaries, reaches out to grasp the natural wealth of the world.

It is becoming more and more important that a mining school should be located at the heart of things; for it needs to be not only permanent, but permanently strong; to maintain relations with capital not less than labor; and to have a cosmopolitan rather than a provincial outlook and sphere. It is as necessary as ever that the mining school should be in close touch with many operating mines. But in modern times this is much more easily effected from commercial than from mining centres. For these reasons, I believe that in the near future the positions of commanding importance will be held by mining schools located near large commercial centres, particularly when these command not one. but many mining districts.

Over-Supply of Mining Schools in America

In a paper on "The Growth of American Mining Schools and their Relation to the Mining Industry," read at the Engineering Congress at the World's Fair at Chicago in 1893,[1] I have already called attention to the relatively small

[1] *Transactions*, XXIII. 444; also, *Transactions* of the Society for the Promotion of Engineering Education, vol. I, 1893.

proportion of miners among the wage-earners of the United States. According to the Tenth Census, the number was only 1.82 per cent of the wage-earners, or 0.63 per cent of the total population. The Eleventh Census showed a similar relation. The figures of the Twelfth Census show the total number of miners and quarry-men to have increased to 1.95 per cent of the total wage-earners, or 0.75 per cent of the population. It is impossible to determine from this report the exact number engaged in metallurgical work, but after a careful study of the data given, a liberal estimate for metallurgical laborers shows that the total cannot be for both industries much more than 2.5 per cent of the wage-earners, or 0.95 per cent of the population.

On the basis of the Eleventh Census (which contained no enumeration of mining or metallurgical engineers) I estimate that there could not have been at that time over 6000 persons in the United States who practiced these professions; and that to keep up the supply would require about 200 new men per year. In the Twelfth Census the mining engineers were enumerated for the first time and the number given is only 2908. Metallurgical engineers are not specified; but under the head of "Chemists, Assayers and Metallurgists" the number is 8887. It is plain that a liberal outside estimate of mining engineers and metallurgists would be ten thousand; and to keep up the supply would take about 330 new men each year. By including assayers, mine-surveyors, and the various minor officials of mining and quarry companies, who might require some technical training, this number might possibly be doubled or even trebled. But when we remember that for many of these positions very little training is required, and that they are open to any one who wishes to attempt the work, including many mining students who fail to graduate, it must be evident that there is a legitimate field for not much over

300 mining-school graduates each year. In 1893 I showed that there already existed in the United States a much larger number of mining schools than was really needed; and the number is now much greater. The attendance at many of these schools has already increased enormously. At the University of California, for instance, the gain has been nearly 1400 per cent since 1887. There is no doubt that the demand for mining engineers in America can easily be supplied by the existing schools. It would be a distinct advantage if they could be restricted to a very much smaller number. Not more than six, or at most a dozen, favorably distributed according to the needs of the mining communities, could do all the work demanded of them much better than a larger number. Under American conditions no regulation but that of natural competition is possible. Much could be gained, however, if the existing schools would coöperate to fix a common standard for the degrees given. While no official relation with the mines is possible, the moral effect of such a step would be very great.

Degrees

One of the reasons that so little attention has been paid in America to college degrees in the past is the great unevenness of the requirements for them in different parts of the country. Whenever a degree, or its equivalent, has come to mean something definite, as with our military and naval academies, it has received full recognition.

Still, there are indications of a general change in the public estimate of degrees. This has been most marked in regard to the degrees of Doctor of Philosophy and of Science. These have come to mean a capacity for original investigation in some branch of science or letters. It would be a distinct advantage to the mining schools, and to the

mining profession, if a similar definite meaning always went with that of the degree of mining engineer.

At present the practice of American mining schools differs greatly in this matter. Some give the degree of mining engineer at the end of a four years' undergraduate course. One even gives it in three years; one has attempted a five years' course, but has unfortunately gone out of existence. Others give, for much the same amount of work, only the degree of Bachelor of Science at the end of the undergraduate course, and reserve the degree of mining engineer for advanced work.

I am convinced that no matter how excellent the course of a mining school, it is a distinct mistake to give the degree of mining engineer on the same basis as that of the bachelor's degree. Some engineering schools, recognizing this difficulty, have attempted to institute as a mark of greater attainment the absurd degree of doctor of engineering.

The highest degree given by a mining school should be that of Mining Engineer. This degree should be put on the same basis as that of Doctor of Philosophy, or of Science. It should be confined to those who have not only mastered the fundamental training, but have shown by actual accomplishment that they possess, in addition, the precious qualities of initiative and capacity as leaders in engineering, and also that maturity of mind and character which one naturally associates with the profession of the engineer. If this standard could be maintained, the degree of Mining Engineer from an American mining school, in spite of its disconnection with Government service, would soon stand higher than that of any other country in the world.

It must be evident that it is not possible to crowd a complete technical education into a four years' course, without neglecting the broad basal training that is necessary for

advanced work. But if some such plan as I have outlined were adopted by the leading American mining schools, a great advance would be made.

A large number of men could then take advantage of the under-graduate course which would then, in a new sense, and in a much higher form, take the place of the *Bergschule.* In this school all would receive the fundamental training necessary for the mining engineer, together with some knowledge of the various technical branches. After finishing this course of four years, and receiving the bachelor's degree, the best thing for all to do would be, as a rule, to plunge directly into the realities of the mining life. All could then step at once into the lower ranks of the profession. Most would undoubtedly be contented to remain there, filling a useful place in the general scheme, now occupied by men without either scientific or technical training, thus raising the standard of the entire industry. But the chosen few who possess the creative faculty of the engineer should be encouraged to find their special bent and field as soon as possible, and then to throw their whole strength into a real mastery of the chosen specialty. A man is then in a position to specialize as much as may be necessary without becoming narrow. Three years of mature work along these special lines, in graduate work, either in college, or under proper conditions, outside of it, should lead to the production of a piece of original work which would justly entitle him to the degree of Mining Engineer.

Such a policy would parallel, without imitating, the methods that have been so successful in encouraging advanced and independent workers in our universities. It would create an American *Bergakademie* that would be superior to anything of the kind in Europe. And it would secure for America, by a process of natural selection, a body of mining engineers worthy of their natural heritage.

THE RELATIONS OF ELECTRICAL ENGINEERING TO OTHER BRANCHES OF ENGINEERING

BY ARTHUR EDWIN KENNELLY

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ENGINEERING is coeval with civilization. Its crude beginnings must have evolved with the first banding of men together for a common purpose. In a very broad sense of the term, engineering comprises all material construction and operation executed by a community through the efforts of a specially selected few. The degree to which engineering is carried in a community is a measure and criterion of the degree of its material civilization. *Ex pede Herculem.* The pyramids of Ghizeh and the Cloaca Maxima at Rome clearly reveal by inference the status of their respective communities at the dates of those constructions.

In the same broad sense, engineering lays every art and science under contribution. But whereas the branches of engineering dealing with architecture, mechanics, mining, ship-building, road-making, and hydraulics go back to prehistoric times, steam engineering and electrical engineering are of comparatively recent date, steam engineering being about two hundred years old and electrical engineering about seventy. These youngest branches of engineering

have completely changed the aspects of the parent tree. Without them modern civilization could not exist.

Each new industrial application of electricity has opened a new field for electrical engineering. The electric land telegraph first opened commercially in 1835. The electric submarine telegraph commenced in 1850. Since 1870 the electric dynamo and motor, the electric telephone, the electric arc and incandescent light, the electric furnace, the electric railway, and the electric wireless telegraph have all come into existence. These industrial applications have jointly created an applied science and an art with a large and rapidly growing literature, language, and technology. In the United States alone it is estimated that these industries have a total investment of three billions of dollars and employ 400,000 workers.

The most significant difference between electrical engineering and all other engineering lies in the fact that electrical engineering deals with the application and control of wave-movements propagated through the universal ether with the speed of light; whereas all other engineering deals with the mutual relations between material substances. In other words, electrical engineering is the controlled operation of the immaterial upon the material. All other engineering is the controlled operation of the material upon the material.

A projectile may be fired from a cannon over a thirty-kilometer range at an initial velocity of about one kilometer per second. A locomotive may be driven over a smooth level track at a speed of fifty or sixty meters per second; but an electric impulse will travel over a wire at a speed of 300,000 kilometers per second. Both the projectile and the locomotive must displace the air through which they move, producing violent frictional disturbance of the medium. The electric impulse moves through the

air without friction or appreciable disturbance. Hence the wonderful adaptability of electricity to play the part once assigned to the winged Mercury among the gods on Mount Olympus, and by its enormous speed to annihilate distances.

In nearly all industrial electrical applications, energy is transmitted over wires, and it is the transmissibility of electrical energy which gives its principal value. The energy is transmitted from convenient sources, or points of generation, to sinks or consumption points, where the energy is abstracted and converted. In some cases it is directly converted by electric motors into mechanical work. In other cases, it is converted into heat, as in electric furnaces for heating, or in electric lamps for lighting. In yet other cases it is converted into mechanical energy, not for doing work, but for communicating intelligence, as in the telegraphic receiving-instrument. But in all these cases the electric energy is carried to the point of consumption and delivery through the ether, guided by the wire or wires. The interior of the wire is the only place where the transmitted energy does not flow, for whatever energy enters the wire is wasted therein as heat, and fails to reach its destination.

Prior to the introduction of the steam engine, men worked in two ways; first, as intelligent beings exercising skill and judgment; second, as muscular machines, or peripatetic sources of brute force, like beasts of burden, with vestiges of intelligence. This segregation of a large section of the people into competition with animals tended to brutalize all men, both the muscular machines and the more intelligent beings over them. Coal and the steam engine gave a great lift to humanity by removing the competition of human muscle with brute muscle. The applications of electricity have so far aided the uplifting process, by the

improved distribution of power, that not only are men emancipated in civilized communities from draught-service or mere animal-haulage, but even horse-haulage in large cities has commenced to be uneconomical.

From an economical standpoint, electrical engineering coöperates with other branches of engineering in distributing either special utilities exclusively, or general utilities with particular advantages. Distributions of the former class are intelligence and power. Distributions of the latter class are light and heat. That is to say, the telegraph and telephone maintain a monopoly of the rapid transmission of ideas. The electric motor has almost a monopoly of the distant transmission of power. But electric light is in competition with other forms of illuminant, and maintains its present position by virtue of convenience, cleanliness, or other special qualities.

The sociological advantages derived from the electric telegraph and telephone are enormous. If, as has been claimed, the invention of the logarithm-table has virtually doubled the lives of astronomers, the invention of these electric implements has virtually doubled the lives of business-men. Moreover, our modern systems of government would be impracticable in the absence of these instrumentalities. It is stated that in the year 1815, prior to the electric telegraph, the news of the battle of New Orleans was not received in the national capital, Washington, for three weeks. On the other hand, in 1898, the news of the battle of Manila was reported in Washington a few hours after it occurred, by actual time; or, some hours before it occurred, by local Washington time.

As regards the electrical distribution of power, the convenience with which insulated wires may be carried and distributed to motors in and among buildings has profoundly affected the construction and operation of modern

factories, where the long overhead rows of constantly running countershafting, with large numbers of endless belts thence descending to machine tools, has been replaced to a considerable extent by a clear headway for cranes, and an electric motor on each machine tool or near to each group of tools. The complete control of tool-speed which this system provides and the cessation of all waste of power in running friction when a tool is out of use, are great advantages in favor of electric factory driving.

The contrast between the transmission of power by electricity and that by rope-haulage is very remarkable. A steel cable in a rope-drive can transmit say 300 kilowatts (about 400 horse-power) to a distance of a few kilometers by its bodily movement at the rate of a few meters per second. On the other hand, a quiescent electric cable of copper, suspended on the insulators of a pole line, can transmit 3000 kilowatts to a distance of a few hundred kilometers, with about the same efficiency. In the case of the mechanical transmission, the wear and tear and depreciation of the steel cable is considerable. In the case of the electric transmission, the wear and tear of the conductor has never yet been detected. The depreciation is practically limited to that of the poles, insulators, and mechanical supports. So far as is yet known, an electric conductor does not wear out electrically by the exercise of its functions.

At the present time, the longest commercial electric power transmission is in California, from de Sabla water-power house, in the foot-hills of the Sierra Nevada, to Sausalito, opposite San Francisco, a distance of 232 miles (373 kilometers); while 7500 kilowatts (10,000 horse-power) is regularly transmitted from Electra, another water-power house in the Sierras, to San Francisco, a distance of 147 miles (236 kilometers). It would seem as if it were only

a question of time when every important waterfall shall be harnessed to turbines and dynamos for the transmission of solar energy to the nearest mart.

Up to the present time, the coal-supplies of the world have kept us amply furnished with power at low rates. With coal averaging say $2.25 per metric ton in the Eastern United States, the cost of a kilowatt-hour at the steam-engine shaft during the working hours of the year is from 1.75 cents in small plants to 1.33 cents in larger plants, with good management and economy. It is estimated that the world's total output of coal is approximately two millions of metric tons daily. At the present rapidly increasing rate of consumption, the cost of coal delivery tends slowly to increase. Unless, therefore, discoveries are made of new available sources of power, the value of solar power may be expected to appreciate. The only solar engine of large power that has thus far been made effective, or which promises to be effective in the near future, is the waterfall. Already several hundreds of thousands of kilowatts of the world's water-power are electrically converted from waste to utility. In the single instance of Niagara Falls, about 100,000 kilowatts are already utilized, and plans now in progress promise to develop a total of about 500,000 kilowatts more. This electrical power is sold to consumers in the vicinity of the Niagara power-house at about a quarter of a cent per kilowatt-hour, in large quantities, continuously.

One of the greatest advantages which electrical engineering has rendered and is rendering to the people is in cheapening and accelerating transportation by the electric streetcar and railroad. In a number of American cities it is possible to travel for five cents any distance in one direction up to 10, 15, or even 20 miles, at a scheduled speed of from 7 to 12 miles per hour, and with cars on headway of

from 2 to 15 minutes. The reason for the cost of transportation being so low is that the electric street-car is easily controlled, can be started and stopped at small expense, and requires no private roadbed or right of way. The effect of this reduction in time and cost of transportation is to increase the available area and diminish the density of urban population. This rapid transit acts as a distinct check to the modern tendency of overcrowding city districts. It averages more nearly the values of real estate and improves hygienic conditions. In 1902 the number of passengers reported to have been carried by the steam railroads of the United States was about 600 millions; while those carried by the electric railroads was about 4800 millions; or eight times as many. The average steam-railroad distance of travel was 30 miles for a fare of 60 cents or very slightly over 2 cents per mile. The average electric street-railroad fare was very nearly 5 cents. The electric railroads carried the entire population on the average 63 times during the year; while the steam railroads carried the population nearly 8 times. But whereas the steam railroad passengers carried had increased only 5% in the decade prior to 1902, the electric passengers carried had increased 137% in the same time.

Not only has the electric railroad given cheap and convenient urban and suburban traveling; but it has also largely removed the preëxisting discomforts of such travel to dust and smoke, so that electric railroad traveling is frequently resorted to for pleasure; while steam railroad traveling is usually only resorted to for reaching a destination.

From a constructive standpoint, electrical engineering has had a marked beneficial influence upon other branches of engineering. For example, it has developed the capacity of steam and hydraulic prime movers. The largest sta-

tionary steam engines and the largest hydraulic turbines have been called into existence by the demand for electric power distributions. The high-speed reciprocating steam engine was developed to meet the requirements of dynamos. The most recent and highest speed type of steam engine—the steam turbine—could hardly have been utilized or developed for stationary work in the absence of electric power plants. These steam turbines, while only of very recent growth, offer a working efficiency comparable with that of the best reciprocating steam engines; while they have markedly reduced the expense of material, construction, floor-space, foundations, and operation. At the present rate of progress, it would seem as though the reciprocating steam engine would eventually be superseded by the rotary steam engine. Conversely, this improvement in steam engineering is reacting to the benefit of electrical engineering by reducing the size and cost of steam dynamos and the price of electric power in distributing-systems.

The development of any one branch of engineering inevitably stimulates other branches. The reduction in the cost of electric power for machine-driving thus promotes activity in the construction of all kinds of machinery.

The development of electrical engineering has also tended to increase the accuracy and precision of other branches of engineering; first, by simplifying the delivery and measurement of power, and second, by the introduction into engineering of a scientific system of units.

Mechanical power is delivered from one body or system to another through mechanical contact, or the pressure of one material system upon its neighbor. In general, the power transmitted is equal to the product of the effective pressure, or tension, and the velocity at which it is delivered. In most cases it is very difficult to determine the magnitude of the effective pressure. In the electric trans-

mission of power, the power is delivered through an electric conducting circuit, and while in the circuit is equal to the product of a certain voltage and a certain current strength. This product—the electric power—is readily capable of precise measurement. Consequently, the most convenient and accurate method of measuring the delivery of mechanical power is usually by electrical means through the intervention of an electric circuit. Thus the power which a machine receives from moment to moment in the performance of its duty, or the total energy which it receives in the course of a given period of time, may be determined with great convenience and a high degree of commercial accuracy by electrical measuring-instruments placed in the circuit of a motor coupled to the machine. By the accumulation of such observations and experience the knowledge of the behavior of machinery has been greatly augmented since the general introduction of dynamos and motors.

It is a remarkable fact that in spite of our lack of knowledge as to the precise fundamental nature of electricity and magnetism, the knowledge of their action and control should already be so definite and precise. In many instances it is possible to design and predetermine the behavior of electric machines as closely as it is possible to determine their behavior experimentally after being built, under commercial or factory conditions. That is to say, a skilled designer, accustomed to a certain class of dynamo machines, can frequently compute the characteristic properties of a new dynamo or motor, as laid out on paper, to as close a degree of accuracy as those properties can be measured, under commercial conditions, after the machine takes material form. This general precision of electrical engineering has aided engineering in general to become an exact science.

Electrical engineering has adopted by international convention a system of electromagnetic units which is based upon the international metric system, and which has the advantages of being simple, decimal and international. This has tended to give precision and definiteness to all electrical engineering measurements. In other branches of engineering, the custom varies in different countries, thus in hydraulic engineering, the cubic foot (of water), the cubic yard, the short ton, the long ton, the metric ton, the liter, the British gallon and the U. S. gallon are all promiscuously used in such a manner that measurements in one country are frequently unavailable to engineers in other countries without lengthy arithmetical reduction. This is a most unfortunate diversity. Again, in mechanical engineering, the foot-pound-per-second, the foot-ton-per-second (long and short), the British horse-power, the European continental horse-power, the poncelet, and the kilogramme-meter-per-second, are all in use as units of power. Unless qualified as to standard geographic latitude, they are all subject to variation within a quarter of one per cent above or below the mean, owing to the variation in the force of gravitation with terrestrial latitude. On the other hand, the electric unit of power, the watt, is independent of the latitude, or even of the planet, and besides being an international mechanical unit, is also an electrical circuit unit. For these reasons the kilowatt (1000 watts or about 1⅓ horse-power) is at present steadily displacing the horse-power in engineering literature, all over the world.

Electrical engineering has exercised a marked intellectual influence upon the time, in the direction of mathematics. Applied electricity is particularly subservient to simple mathematical law, which is but another way of stating that the present applications of electricity are well

understood. Prior to the development of electrical engineering, the useful applications of mathematics to engineering were almost limited to mechanics, statics, and kinetics. Now, electrical engineering has thrown open to application the entire stock of mathematical physics which has been accumulating for several centuries. Consequently, it is now not only difficult to find a department of mathematical science which does not have applications useful in engineering; but engineering has also found, and is constantly discovering, new fields for profitable exploration by the mathematician. In the last few decades, departments of mathematical analysis which had previously been regarded as pure, or inapplicable, are now strained to their known limits for giving practical service to engineers. Moreover, there are many directions in which engineering would be applied, if mathematics could only gain a reliable foothold on the outcrop.

In any new application of science, first comes the fact discoverer, then the mathematician, who quantitatively connects the newly discovered phenomenon with the known environment. Next in succession is the inventor, who grasps the utilitarian possibility of the fact; then the engineer who grasps the essential portions of the already enunciated mathematical law, and relates the same to commercial and constructional conditions. Finally, the capitalist grasps from the engineer the commercial limitations of the reduced law and estimates the commercial values of the utility, venturing capital upon the new possibility on the risk of its desirability or undesirability. In rare cases it is possible for any successive number, or all of these intellectual stages to be reached in one and the same individual; but it seems to be a general sociological and intellectual law that the capitalist will not risk the savings of past labor on a new application of science until the engineer has intellect-

ually assimilated the problem from an arithmetical standpoint, with due regard to physics and mechanics on the one hand and to the cost of factory processes on the other. In his turn the engineer is often unable to grasp the problem arithmetically until the mathematician has intellectually apprehended and elucidated the quantitative scientific relations of the problem to a reasonable degree of completeness.

Thus, for example, considering the modern dynamo, first came the discovery of the phenomenon of electro-magnetic induction by Faraday; then the work of mathematicians, like Ohm and Ampère, to determine the quantitative relations of the phenomenon to the known cosmos. Thus far the matter was pure science. Then came inventors who conceived the idea of utilizing the new principle for the industrial generation of electricity. Unless, however, the inventor was himself an engineer or was assisted by an engineer, the idea would have been practically unavailing, however important the idea might be in directing attention to the possible use of the new phenomenon. The work of the engineer was next necessary to design the machine. This he could only do effectively according to his apprehension of the mathematical, physical, and mechanical underlying laws already discovered, and the application of those laws in such a manner as to fit factory methods of construction economically. Then came the capitalist ready to venture the accumulated savings of the community he represented, upon the project of building dynamos for commercial purposes, as soon as he was satisfied as to the commercial desirability and economy of the new process.

In reality the modern large dynamo has had to undergo many such successive stages of intellectual and material preparation, in order to reach its present stage of development. Frequently the capitalist would have preferred to

install larger dynamos than existed at the time, but could not risk their being unduly enlarged because the engineer could not be sure of the results, and the engineer could not see his way clear for want of existing scientific and mathematical knowledge in the direction considered.

Although the above sequence of relations is generally admitted to be self-evident on consideration, yet the perception of these relations by the community at large seems to be a matter of social and economical importance; because the more clearly that organized society apprehends the steps of the processes by which it ultimately secures what it needs, the more effectively it is likely to stimulate the activities which lead to those steps. It is of importance to the whole world that there should be an adequate distribution of activity in all these stages of effort to secure new gifts from nature. There should be plenty of work in physical and scientific laboratories for the discovery of new facts. There should also be plenty of mathematical work carried on to interweave and connect these facts with the great universe of quantitative relations. There should be plenty of stimulus and reward for inventors to find useful applications for the new facts. There should be plenty of engineering work devoted to controlling the facts by reducing the purely mathematical relations of all time to the commercial mathematical relations of the locality and momentary time. Finally there should be abundant opportunity for the business-men acquainted with the needs of the community to ascertain the results and possibilities of engineering development as well as adequate reward for the successful investment of capital in such enterprises as they consider the engineers can offer and the community will accept.

In line with these ideas it is found that even to-day large industrial corporations finance new scientific applications in their line of work, maintain their own corps of engineers

and inventors, and their own research laboratories with scientific experts. Already, therefore, these corporations consider that it is economically desirable to develop simultaneously in their own body all these successive stages of intellectual and material effort. If this be the trend of individual engineering industries, it is reasonable to expect that the future trend of larger communities will be in a similar direction. That is to say, cities or nations may in the future consider it economical to foster either directly or indirectly any or all of these stages of intellectual activity which conjointly lead to new material wealth, on the principle that properly organized activity for any purpose is more effective than spontaneous, sporadic and disorganized efforts of individuals in the same direction. Wonderful possibilities lie before organized scientific research and organized creative engineering based upon the same.

From the psychological standpoint, electrical engineering has come to exercise a marked influence upon civilization. These psychological conditions are important, because if we compare the condition of the world to-day with that which is reflected to us from the history of past times, we are impelled to recognize that there are two salient differences between them. One is the increase in later times of material wealth, including processes, utilities, and conveniences, such as steel structures, the railway, or the printing-press. The other is the change in the general mental attitude of human beings toward each other and toward their surroundings. That is to say, one salient change is material in nature; while the other is psychological. It cannot be denied that both are of great importance to the progress of civilization, and perhaps the one is as important as the other. The attitude of mind of the ancient Egyptians, as reflected in their writings and remanent structures, must have been markedly different from that of the Greeks

in the days of Homer, or from that of the Romans under Nero, or from that of Europeans during the Middle Ages, or from that of the peoples in the modern civilized world. In a certain sense, the psychological condition reflected in a community transcends in importance its material conditions. The development of a worthy and potent psychological condition in a people is even more important, from this view-point, than the development of a great and ample material condition. The one is probably necessary to a highly developed state of the other.

The effect of electrical engineering applications on the psychology of the community has been greatly to extend the radius of mental influence of the individual. In the days before the discovery of written language, the intellectual sphere of influence of an individual was limited in radius to that distance at which his voice could be heard. Beyond that distance his influence could only be transmitted either by his personal migration with respect to his neighbors or by the migration of his auditors and their repetition of his ideas from memory. Gradually, after writing became a familiar mental habit, written words superseded repeated speech, and document, tradition. Writing thus vastly increased the effective sphere of psychological influence, although the diffusivity of the new method must have been but small. Engineering steadily enlarged the sphere of influence by developing the press, the railroad, and the steamship, by which the written word could be reduplicated and carried faster and farther. The old semaphore telegraph from hill to hill, still found in various parts of Europe in sequestered desuetude, went a step further and added speed to the travel of thought; but the electric telegraph and telephone have enormously increased the range of mental influence. Even now the fetters of thought are closing upon the arms of the ocean, and wireless telegraphy prom-

ises in time to extend the transfer of ideas to the uttermost distances of the sea. The effect is multifold. The tendency is always for the best intelligence to have its influence most widely distributed, considering the best as that which the community esteems best at the time; so that the extension of the range of mental influence always tends for the benefit of the many and the selection of the fittest. The consciousness of the individual being able to influence his neighbors at any distance on the planet gives him greater confidence in the success of undertakings dependent for their effect upon widespread coöperation. The consciousness of the individual that he is always within the sphere of influence of his leader exerts a great psychological supporting influence in times of difficulty and doubt. It is equivalent to a bridging over of the distance between the strong and the weak. Any one who has ever received from land a telegram when far out at sea, either by wireless telegraphy, or by a lifted submarine cable, will testify to the intensity of this psychological influence.

According to the census returns of 1902 the number of telegrams forwarded commercially during that year in the United States was 91,650,000; or 1.2 telegrams per annum per head of population, at an average cost per message of 31.8 cents. In the same year the number of reported telephonic conversations in the United States was nearly 4950 millions, or 65 per head of population, at an average cost per conversation of 1.65 cents.

Along with the swift and extended radius of thought that electrical engineering offers, by the mutual relations of immaterial mentality and the immaterial ether, there is also necessarily involved a reduction of psychological restraint and an extension of psychological freedom. A part at least of the discomfort of human beings often arises from a disconformity between their modes of thought and of their

mental relations to those of the individuals surrounding them. Occasionally an individual who is psychologically ill-adjusted to his environment, and who is therefore ineffective in his coöperation with it, may subsequently become more usefully effective in response to a changed mental environment. The greater and swifter the radius of thought activity under the influence of engineering methods, the greater the stimulation to migration that leads from a lesser to a greater harmony of adjustment between the internal and external mental activities of the individual, to the increase of general comfort and well-being. The segregation of associable mental activities is simplified and rendered frictionless by whatever extends the rate and range of ideas.

In its moral effect upon the community at large, electrical engineering must have the same effect as all other branches of engineering; namely, to dispel illusion, dignify all labor, exalt truth and precision, gradually eliminate superstition, bring home to consciousness the infinite simplicity of nature, and indicate that no good thing can be humanly acquired without effort and training.

In a certain sense engineering is destined to assist in effecting the apotheosis of humanity. Every step taken by the people along the path of civilization makes degeneration to dissociative barbarism the more difficult and unlikely. The methods that men adopt to subject the immediate universe to their will react by subjecting their will to the laws of the universe. Centuries ago men dreamed of the civilization that they, by uniting and coöperating, might initiate for their successors to attain. Already that civilization has so far dawned that it has modified us to its requirements, and we live for it as well by it. The difficulty of fitting ourselves for it is greater than that of fitting it for us. Whatever modifications civilization may

undergo in the course of time must be molded in accordance with the developments of engineering, which are themselves but the interpretations into human ideals of the attributes of nature.